Practical Shellfish Farming

by: Phil Schwind

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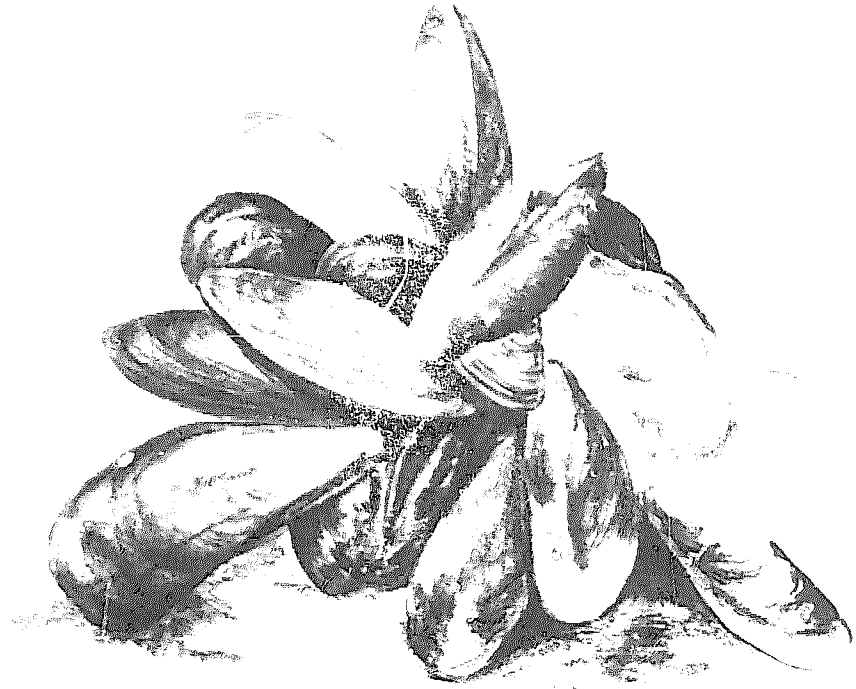

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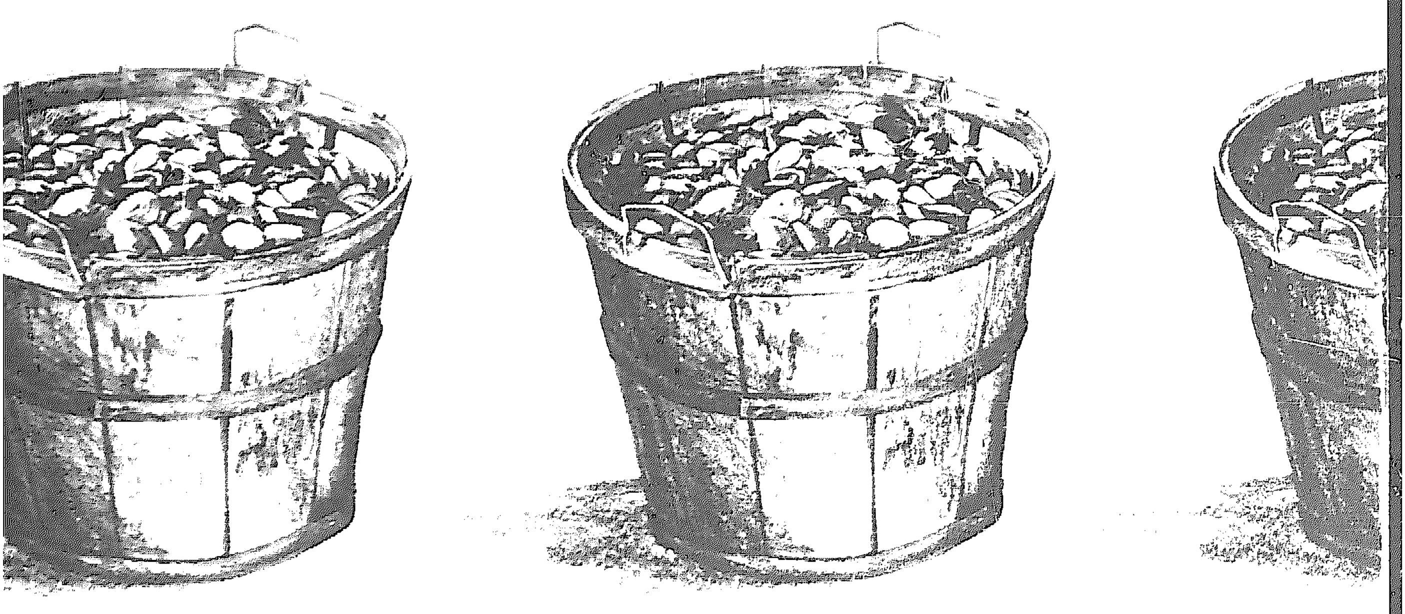

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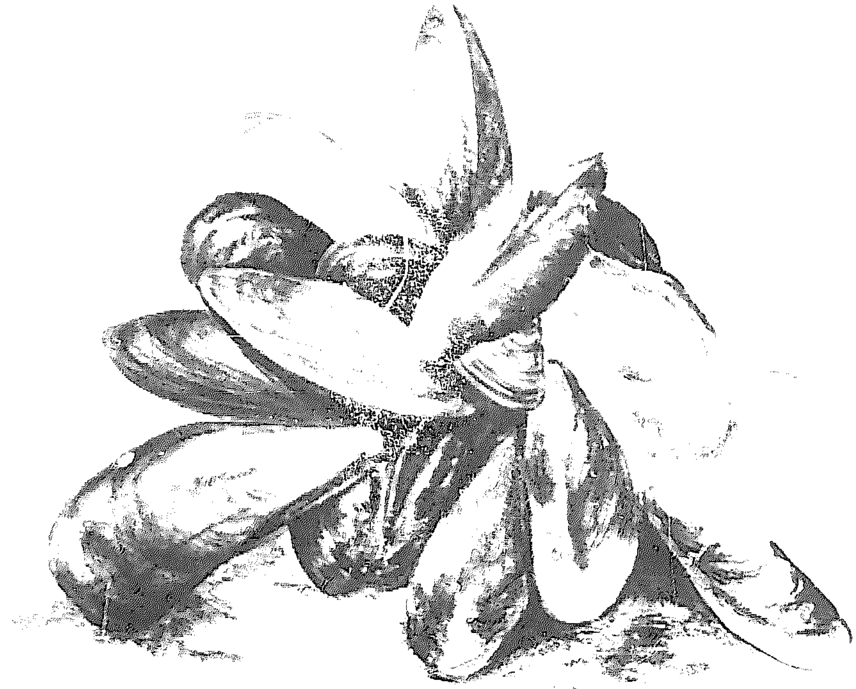

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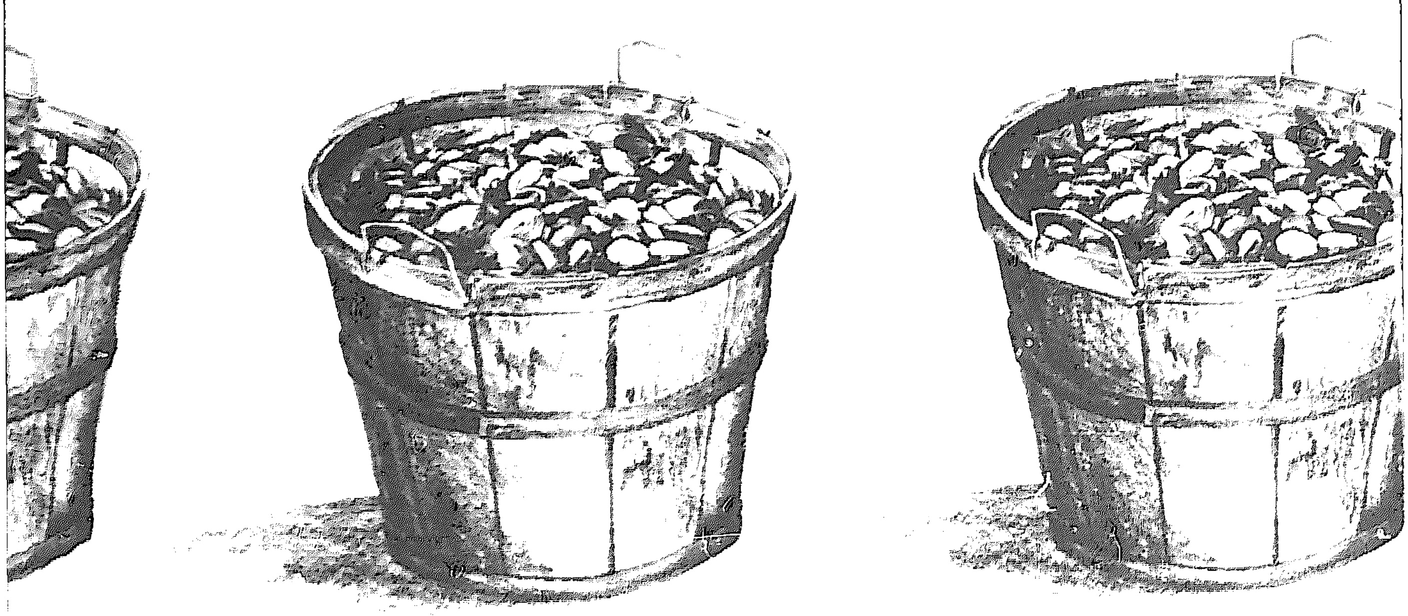

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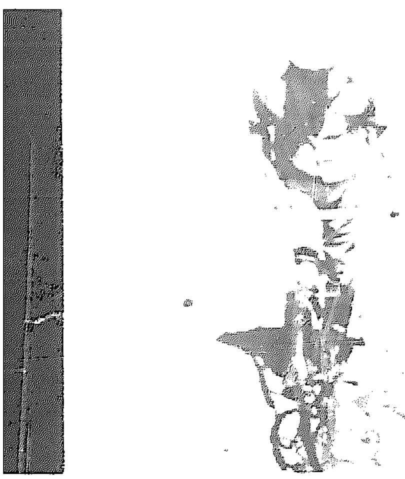

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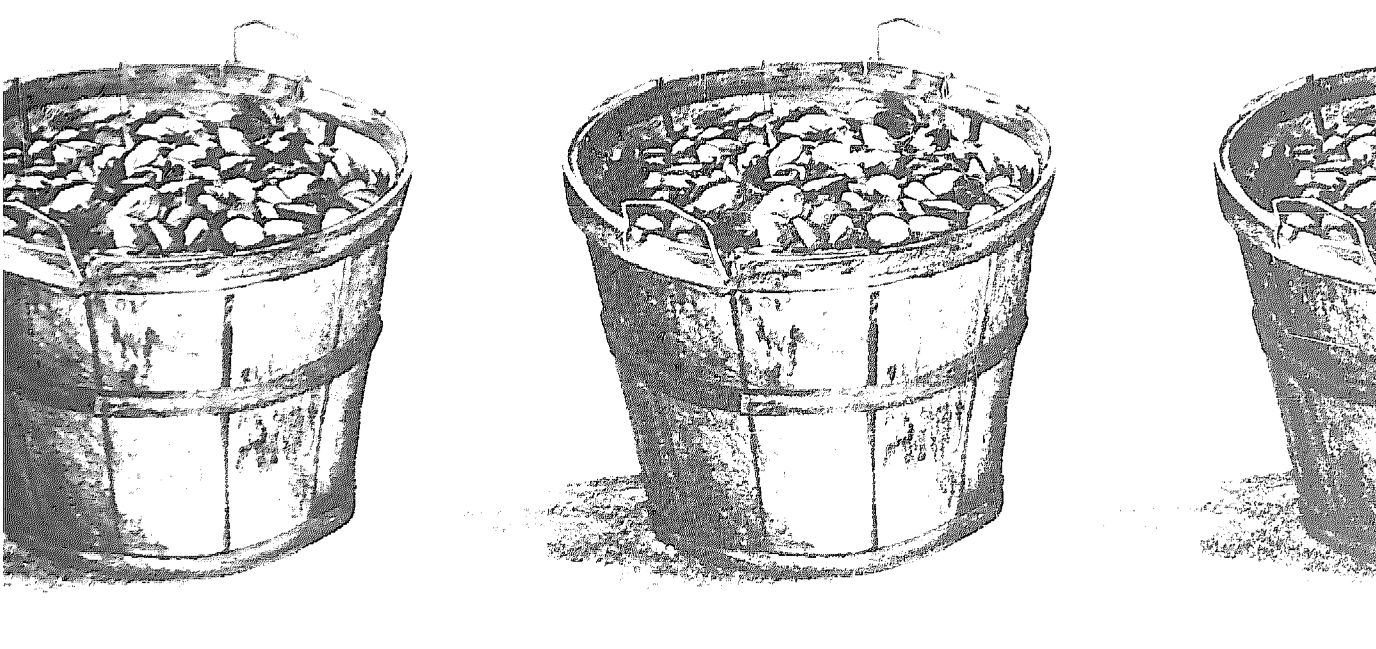

Practical Shellfish Farming

By Phil Schwind

Illustrated by
Coralee Spacht Hays

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PREFACE

Imagine a farm where little or no ground preparation, plowing or harrowing is necessary after the first year, where seed is either given to you by nature or can be bought for a minimal price from a hatchery, where the only cultivation necessary is done by harvesting your crop, where neither drought nor rain is a problem, where fertilizer is supplied and spread free, where blight is almost unknown and there is little disease, where some of the predators are in themselves a money crop and most of the others reasonably controlled with a minimum of hand work, where your produce can be held if the price is down or sold if the price is up, and where your land is all but tax free.

That is a saltwater shellfish farm.

Over and above all these benefits, you may be supplying the neighboring public lands with seed at no cost to you, the town, or the state, and you will be taking the pressure off the public lands by working your own farm instead of fighting for your uncertain share of a natural crop. In addition, you will be assured of top prices for all you raise because you will have a uniform, dependable, high-grade product, and, while you are doing all this, you may be utilizing presently barren, unproductive land.

But, you say, if it is all so easy, why isn't there more of it going on? Give it a little time and a little more pressure on the shellfish industry – there will be soon. There was a time when a goodly number of men made their living shooting ducks for market. No more: too many gunners, too few birds. In most places commercial freshwater fishing is a thing of the past. Too many fishermen put an end to that: nature couldn't meet the demand. The areas along the coast where a shellfisherman can dig all the "wild," nature-given shellfish the market will stand become fewer and fewer. Too many fishermen, too eager a market. Most of the coast is over-fished, polluted, or, for whatever reason, barren. Now is the time when shellfishermen are going to be faced with the same problems which gave rise to game farms and fish hatcheries.

But the problems are much simpler than those facing game farms and fish hatcheries. No elaborate pens, pools, or structures are involved, no highly specialized food cuts into the profits, for nature supplies the diatoms and planktonic growths which are the natural food for growing shellfish. The land is public land, leased from the state or town at ridiculously low prices.

This, then, is the reason for this book: to let you profit by our experiences shellfish farming on Cape Cod. It is not a scientific treatise defining "the parameters of ongoing disciplines." In it Latin terms do not proliferate. It is based on hard, profit-making experience. I suppose, as Shellfish Constable for the Town of Eastham on Cape Cod for the last ten years, I owe something to the town for paying me while we have learned the hard way, but we *have learned*, our shellfisheries *have* increased ten-fold, and the future looks very bright.

Pollution and its cure, and the reclamation of polluted lands are beyond the scope of this book, but we can and will deal with the problems of fished-out areas and some barren flats. We will have to do with quahogs (*Mercenaria mercenaria*), clams (*Mya arenaria*), American oysters (*Crassostrea* or *Ostrea virginica*) and blue mussels (*Mytilus edulis*), leaving out such peregrinating shellfish as bay scallops (*Aequipecten* or *Pecten* *irradians*), sea clams (*Spisula solidissima*), and razor clams (*Ensis directus*). (And may that be an end, so far as possible, to Latin terms.) We will discuss both bottom culture and rafting, or off-bottom, methods. The facts herein included are facts, not theories.

While it is true that practices vary according to local conditions, nearly all of the book should be adaptable to most of the coastline. Our farming was done in Massachusetts, so special attention is paid to pertinent Massachusetts laws, with a brief summary of "grant" laws in the other New England states. Before you plunge into the business, check with the local authorities. Some of them will be found to be cooperative.

Only one obstacle is found with distressing frequency – the unthinking, insular antagonism toward leasing public land for private enterprise. Education – understanding of the fact that shellfish seed in its larval stage drifts and swims unrestricted for days on end and may just as well stock any flat in town as the flats surrounding its source – seems to be the only tool with which to combat this prejudice.

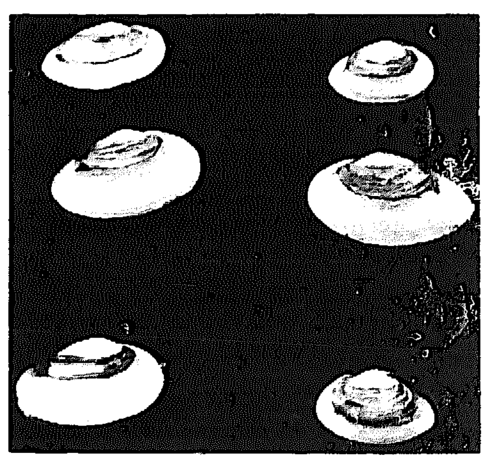
We farmed and are farming this way. You can, too.

INTRODUCTION

HISTORY OF THE LOCAL SHELLFISH INDUSTRY

It may come as kind of a shock that commercial shellfishing as we know it today is a relatively new industry. While the Indians undoubtedly ate a great many shellfish (witness the midden heaps of shells all along the coast) and the early settlers were somewhat pleased to be saved from starving by the quantities of shellfish along the shore, shellfishing as a business is, for the most part, less than a hundred years old.

Oyster farming was the earliest industry in this area. All the native oysters had been eaten, and, more important, the shells on which the spat or seed should have collected had been burned for lime to make fertilizer for farms and plaster for houses. Eventually, the local towns were forced to make stringent regulations to control the taking of oysters. It was, then, just before 1860 that oyster seed was imported and oyster farms developed. Rather surprisingly, in view of the present markets, most of the oysters thus farmed were shipped north, Cape Cod oysters going largely to Boston and Salem, Massachusetts, and Portland, Maine.



These pictures were in an album found in the attic of a house in Wellfleet, Massachusetts, by Mrs. Marguerite ("Maggie") Holway, Shellfish Constable for the Town of Truro, Massachusetts.

Judging from all the evidence in the album, the pictures were taken some time before 1912, on "White Flat" in Plymouth, (Mass.) Harbor. It should be kept in mind that up to this time soft-shell clams were used largely for salt bait, and that so far as edibility was concerned, they were considered "poverty food," to be eaten only when there was nothing else.

The extreme density of the clam population as shown in the top picture is the obvious reason for transplanting. The fact that the clams were probably to be shucked, salted, and sold as codfish bait is the reason the clams, seemingly large enough for the present-day market, could be transplanted profitably.

Elsewhere in the album there is a caption that indicates that the middle photo ("Waiting for the tide to go down before transplanting") shows 84 buckets dug for transplanting.

The bottom left photo shows furrows that were apparently dug by hand with shovels. The clams were then spread very thinly, and, since the area was very wet, they were left to be covered by their own efforts and the wash of the incoming tide. The flat shown was dug over and planted on one tide. (Miles Standish Monument in Duxbury in the background.)

Bottom right photo: The white area on these clam shells shows an amazing three months' growth. (To quote the typed caption under the picture in the album: "A 400% increase in 3 mos".)

As late as 1912 it was said of quahogs that hardly anyone knew much about them except that they grew in mud and could be harvested with rakes.

Soft-shell clams were largely dug, shucked, and salted in kegs or barrels to be used as bait for groundfish. They have been called "poverty food," with the implication that no one ate clams unless he was pretty hungry.

Scallops were considered poisonous, like tomatoes, so-called "love apples," until a crew of pirates from New Bedford came up into Buzzards Bay and poached the scallops there just before the turn of the century. In Nantucket, which probably produces more bay scallops than any other town in the scallops' limited range, if the history books can be believed, scalloping never caught on until about 1910.

Blue mussels, in spite of the fact they have been western Europe's biggest shellfish crop for centuries, were locally used solely for bait except among a few ethnic groups, and could be bought for as little as forty cents a bushel – and a big bushel at that – no more than ten years ago. They are still considered predators, or at least nuisances, and are destroyed at town expense in a good many areas today. But the local market is expanding, and the demand is increasing for good, clean, blue mussels.

The Indians may have used sea clam shells for hoes, but it wasn't until soft-shell clams were fished out and the chain restaurants took to slicing up sea clams for "fried clams" that sea clams came into their own. Now they, too, are being fished out.

And how many people do you know today who realize how delicious razor clams are?

I don't mean to imply that people along the shore didn't eat shellfish. Of course they did, but the business of harvesting and shipping shellfish for sale is new. And then, just when a good thing got going, and transportation and refrigeration made it possible to ship shellfish inland, away from the coast, suddenly, as my partner inelegantly put it, "There ain't none" – or not enough, anyway.

That is where the concept of shellfish farming comes in. It is not all that new, really. Europeans have done it for years, and there were shellfish grants for oysters in Wellfleet (and I expect elsewhere) in the late 1800s, with as many as 2,000 acres in the one bay under private cultivation. But the Wellfleet grant holders were driven out of business in the early 1900s by, of all people, quahogers. There was suddenly a commercial market for quahogs, but, more important, the concept of free public lands was in conflict with private enterprise, which leased these same public lands and invested capital in them, thus excluding free fishing. The concept of free public lands (land below mean high water) is still the major impediment to the development of shellfish farming.

PUBLIC LANDS VERSUS PRIVATE DEVELOPMENT

While the management, and to a certain extent the control, of the shellfisheries in Massachusetts is left in the hands of the individual towns, the commonwealth has very carefully specified that none of its inhabitants may be deprived of the right to take shellfish for family use (Chapter 130, Section 52 of the General Laws). In fact, the same law requires each town to set aside an area in which commercial shellfishing is prohibited, and, upon payment of a fee to the town, any inhabitant of the commonwealth may take shellfish for family use.

This is all well and good, but unfortunately, there has been no consistent effort by the towns to increase the shellfish supply. Laws have been made by the state specifying minimum size; regulations have been made by the towns limiting the take, the hours and days of taking, and the areas from which shellfish may be taken; and, in some cases, prohibitively expensive permits are issued deliberately. The excuse for this negative legislation is obvious: shellfish are in short supply, so, in order to make what little is left go around, limits are set. How much better it would be to increase the supply. Restrictive legislation has seldom increased the shellfish population. There must be a constructive attitude, an expansion of cultivated and seeded ground, if the shellfish industry is to grow to meet the demand – indeed, if it is to survive at all. This constructive attitude could take the form of public planting, but growth could be achieved much more successfully by the introduction of private capital.

Public development has several drawbacks. It takes money, and that means taxes. Personally, I never thought it fair that a little old lady, living on a fixed income, who hated shellfish or for dietary reasons could not eat them, should be taxed because I wanted to make a living digging shellfish, or because someone else happened to like to eat them. Far more equitable that the person making a profit from the shellfish foot the bill for raising them.

Then there is the uncertainty of the crop (and admittedly this holds true on privately cultivated crops as well). I have seen the time when a town-planted crop of shellfish has been opened to the taxpayers, and it seemed as though there were more people than there were (in this case) oysters – there just weren't enough to go around.

There's a third point against public development. With all due respect to the conscientious shellfish officers who do their best, no public crop is going to be as carefully tended as a private grant, upon which depends a man's income for the year.

ADVANTAGES OF SHELLFISH FARMING

On the other hand, grants leased by private enterprise on public grounds have decided advantages, both to the grantee and to the town. In the first place, if the grant is to someone who was, or still is, a commercial shellfisherman, it is going to take some pressure off the public lands remaining. He is normally going to spend most of his time tending his own farm, from which he can expect a higher return than from fishing on public ground.

Secondly, as mentioned before, by the very nature of the animal, cultivated shellfish are going to help re-stock the public ground, since the tiny larvae drift and swim around for a considerable time before forming a shell and setting, and are just as apt to settle on town beds as on private. If it's a good set, there's enough of it to go around, goodness knows, since most shellfish spawn literally by the millions. And this, too, will improve the public stock.

Thirdly, a carefully tended grant will yield far better returns than "wild" shellfishing. No commercial fisherman loves a fish buyer, but the fish buyer has his side of the argument. If he knows he can absolutely depend on a source of prime stock, then he can afford to pay top prices to secure that supply. Put yourself in the fish buyer's place. If he has to buy his shellfish on the open market, then he must take what he can get. If the weather is bad no fisherman goes. If the fisherman happens to get – well, you know, goes off on an unexpected day off, or if the fisherman can't get the size there is a market for, what's the buyer to do? He's promised the retailer a certain amount of a certain grade – and no supply. But, on the other hand, if he knows the grant holder has a specific number of bushels of a certain grade shellfish, he can afford to pay top prices and probably will.

There is one other advantage, at least to the town or state. That is the reclamation of barren ground. Virginia has made regulations such that you cannot get a grant on natural, oyster-bearing "rocks," so private business has taken over marginal areas, and, if my figures are correct, is producing more oysters per acre in these formerly unproductive areas than are produced on natural beds.

We went over the advantages shellfish farming has over land-side farming in the preface. Other than the initial preparation, removing obvious predators, possibly removing excessive plant growth, also possibly re-conditioning the bottom (that is, harrowing either mechanically or hydraulically, and in some cases sanding or shelling the bottom), there is no bottom preparation necessary. No annual plowing and harrowing, no cover crops to plant, no mulch to plow under, few, if any, rocks to remove (if you've picked your site intelligently). Just go ahead and plant.

Your crop will grow without needing fertilizer: there is enough natural food in the water in most areas for far more shellfish than you will ever grow.

You'll have to worry some about pest control, but there are no expensive chemical sprays to buy and contaminate the water. For the most part, pests can be kept at a minimum with a little handwork, and some of them are a profitable crop in themselves.

Except during the spawning season, when cold rain can make things difficult for larval shellfish, you don't have to worry about rain or drought. North of Cape Cod you may be worried about ice movement in the winter if you are rafting your stock (a method of off-bottom culture), or if it has been planted too high on the shore, but you can sink your rafts below the freezing line and most shellfish will stand an awful lot of freezing in the intertidal zone.

The one really big advantage the shellfish farmer has over his landside counterpart is the time of harvest. You raise potatoes? They have to be dug. You grow peaches? They have to be picked. Any crop on the land-side has to be harvested at the right time, regardless of the market value. Not so with shellfish. The right time to harvest is when the price is right. You have an acre of littlenecks in the fall and the price, for some unaccountable reason, drops. So? Let them sit there. They won't rot and they won't grow much during the winter — they'll still be there next spring. Your crop of marketable clams is big enough to dig but the market is dull. They won't grow much before next summer, and even if they do, they probably won't grow so much you can't sell them. Your increased bulk will more than make up for any winter loss.

Grant Requirements of Several States

There is one other distinct advantage the saltwater farmer holds over the land farmer; he doesn't own the land his farm is on, and thereby isn't burdened with real estate taxes. The land will be leased from the town or state, as the case may be, at token rent. In Massachusetts the rent is not less than $5.00 nor more than $25.00 per acre per year; in Maine, not less than $1.00 nor more than $5.00; in Connecticut, to the highest bidder; and so it goes. (There has arisen recently a growing sentiment that, given a practical period of grace – perhaps three years – to get started, a grant holder should be required to produce more than the token crop previously stipulated. With the ever-increasing demands on shore front property, this trend seems reasonable and, indeed, desirable. It should work no hardship on the serious aquaculturist.)

There are variations from state to state in the grant laws, so you will be well advised to check with your state's department in charge of marine fisheries, whatever it may be called. In Massachusetts the complete code is set out in Chapter 130 of the General Laws, from Section 57 through Section 68-A.

In Rhode Island, you might as well forget it for the present, and I quote: "There is no lease bottom in Rhode Island. The Department of Natural Resources issues leases only for experimental aquaculture, nothing for commercial use. There are a very few old oyster leases still in existence, but apparently no one tries to take them up, and I gather that if they did there would be a big hoohah from the clamming interests." * (Strike a familiar note, Wellfleet?)

In Maine you must be an established resident or taxpayer before you can get a grant, while in Connecticut a grant may be issued to any person or corporation. In Massachusetts, according to Section 57: "The town may grant to any person for a period not exceeding ten years a license to plant, grow and take shellfish . . ." The grant is renewable, as it is in other states.

Again in Massachusetts, Section 59 requires a written application and a survey; Section 60, due notice and a public hearing; Section 61, the grant marked to specifications . . . And so it goes in most of the other coastal states. Both Maine and

*From private correspondence with Ms. Elisabeth Keiffer, Information Editor, New England Marine Resources Program, University of Rhode Island, Narragansett, Rhode Island, (now called the New England Marine Advisory Service). NEMAS monthly bulletin available upon request.

Massachusetts require an annual written report, and Maine has a regulation which allows not more than one-quarter of all the tidal flats and creeks within the community to be under cultivation. But essentially, most of the states have passed laws making it as attractive as possible for the aquaculturist.

Rafting on Your Grant

There has been a relatively recent development so far as the aquaculturist is concerned, an adaptation of the Spanish raft mussel culture and the Japanese raft oyster culture. The key word is "raft." With the Dutch mortality expectancy in bottom oyster culture as high as ninety-four percent in six years, it seems as though there must be a better way. Off-bottom "raft" – aquaculture is certainly headed toward a more profitable method. In October of 1973, Massachusetts enacted a law to make provision for this kind of farm.

Section 68-A of Chapter 130 says in part: "The Selectmen of a town or mayor of a city, upon written application accompanied by plans sufficient to show the intended work, may grant to any person an aquaculture license to grow shellfish by means of rafts, racks, or floats in waters of the commonwealth below the line of extreme low tide . . ."

There follows a section on licensing procedures, the right of appeal, and the periods of tenure and renewal, then:

"Said licensee shall have the right to the exclusive use of the lands and waters within one hundred feet of said racks, rafts and floats for the purpose of growing shellfish thereon, and the licensee shall plainly mark the boundaries of said area. *The Selectmen or Mayor shall permit as a condition of the license such public uses of said waters and lands as are compatible with the aquacultural enterprise.*" (Italics mine.)

There follows a section regarding protection as to theft, disturbing the rafts, tieing a boat to them, and "discharging any substance which may directly or indirectly injure the shellfish."

This is a big step in the right direction, particularly in raising oysters, quahogs, blue mussels and soft-shell clam seed. Most important, off-bottom culture assures protection from predation, it produces more uniform and cleaner stock more quickly, and it makes possible the utilization of bottom in no way suitable for shellfish otherwise.

A COMPARATIVE LOOK AT WESTERN EUROPE

It seems pertinent and interesting to consider the grant situation in western Europe. Quoting from a paper by Dr. H. A. Cole, C.M.G., read at the Sixth Shellfish Conference, Fishmongers' Hall, London, England, May, 1975:

> We have had quite a lot of oyster research during the last 40 years: there has been a striking success in developing hatchery techniques but we have failed to pin-point the causes of the ups and downs in natural production on the beds sufficiently clearly to show how better spatfalls can be produced . . .
>
> We need to know urgently what we can do to improve the spatfall by cultivation of the bottom or by concentration of breeding oysters in selected areas . . . Is there something important in the density at which oysters are laid, so that the simultaneous spawning is stimulated by hormones or similar substances in the water . . .?
>
> *Turning to hatchery production,* I believe that we might all be agreed that *the most urgent task is to work out improved methods of bridging the gap between the hatchery operator and the planter.*

The italics are mine. I point out the sentence because that is exactly what we have been trying to do these last few years, and in some considerable measure have managed to succeed. There is a definite correlation between breeding density and the release of seed shellfish. We have also, with rafting techniques, started to bridge the gap between the hatchery operator and the planter.

Let us move across the Channel to the Netherlands. From "Agricultural Newsletter No. 1, 1976":

> More than a century ago, steps were taken to revive the Dutch oyster industry, which had fallen into a decline. *Beds suitable for*

> *raising oysters were leased to private individuals who wanted to enter the business.* [Italics mine.] Methods were developed to allow oyster spat produced during the summer to be provided with artificial substrate during their settling period following their plankton-like wandering lasting about a fortnight. In this way the number of juvenile oysters to populate the selected beds was considerably improved . . .
>
> Efforts were made [in Yerseke] to maintain an equitable population of 200 plus plots, most of which cover an area of five hectares (13.75 acres), in order to insure the balance and stability of the 10 Dutch oyster farms . . .

To go from Dutch oyster farming to the Dutch mussel industry, and to quote from "Blue Gold"*:

> Mussel farming has existed for more than 300 years in the Netherlands. This mariculture is accomplished on the bottom of the shallow, partially diked or enclosed seas. The mussel farmers here also lease their culture plots from the government.
>
> Spain is the world's largest producer of cultured mussels. The annual yield is in excess of 220,000 tons in the shell. 95 percent of this is derived from the five Galician bays where there are over 3,000 rafts . . .
>
> Two to four average-size mussel rafts (75 feet square) can support a family well, and generally this is a family enterprise, although there are some groups that own 20 or 30 rafts and hire employees. *The water surface upon which the rafts float is leased from the government.* [Italics mine.]

To go back a little in the same booklet: each average raft will support about 700, 30-foot ropes. A 30-foot rope produces over 250 pounds of live mussels annually.

Moving on to France, and still quoting from the same source, the pole or "Bouchot" system of mussel culture is practiced. Eight-inch oak poles are driven into the ocean floor in long rows. The poles are placed about three feet apart and there is about twelve feet between rows.

**Blue Gold*, by C. Graham Hurlburt and Sarah W. Hurlburt, privately printed in Duxbury, Mass., November 1974.

"In the Bay of Aiguillon . . . there are now over two and one-half million poles, more than 59,000 rows of 50 poles each. . . As in Spain the Government of France leases the mussel growing areas to farmers, and most of the bouchots are conducted as a family enterprise . . ."

So you see, shellfish farming is done elsewhere. With adaptations and variations to fit the climatic conditions, there is no good reason it can't be done here.

1 LOCATION

Once you have decided to obtain a grant and have checked the local laws, the major question confronting you is where to have it. Quite ideally, you should pick a known productive spot although in Massachusetts this cannot be an area seeded by the town in the last two years, nor one where there is a heavy natural set, no more than you can lease an area in Virginia where there are natural oyster-bearing rocks. Each shellfish takes a slightly different situation (this will be taken up as we discuss them separately), but if you know your particular choice of shellfish grows where you want your grant, then you are pretty well assured you can raise that kind of shellfish there. Of course, if you are situated so you can put down a token planting of the shellfish you want to grow and watch the results, then you will have definite proof as to whether the location is viable.

If this sort of trial planting is not practical, try to find a few native shellfish and check them to see if they have a reasonable growth rate. (The annual growth ring most shellfish show will give you a clear indication.) Make sure an acid condition in the soil has not eroded the shells (although this may be corrected in some cases by harrowing or cultivating).

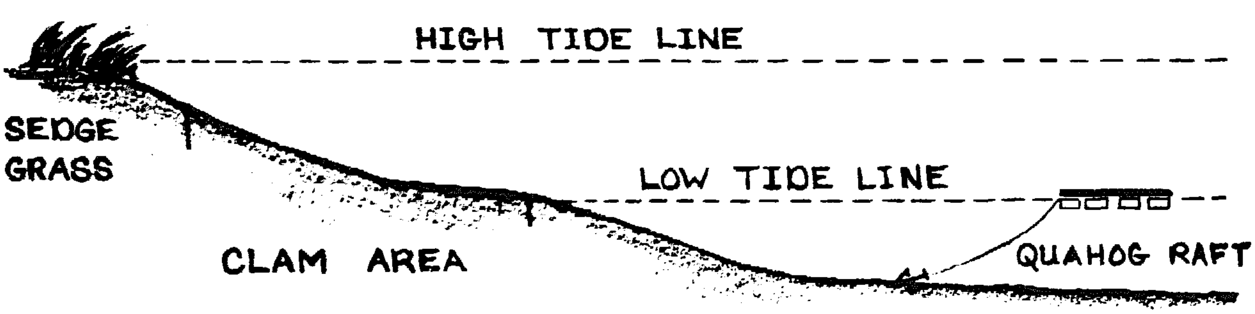
Another of the determining factors is accessibility. Can you drive to the edge of the spot you have picked, or must you go by boat? It will make a difference in labor and time. Maine has a regulation (paragraph 4304, section 7) which gives priority to an adjacent proprietor if he so desires, if there are two or more applicants for the same site. It is highly improbable you will pick a site where the riparian owner will protest your project.

Dr. David L. Belding, author of a 1912 report on quahog and oyster fisheries of Massachusetts, pointed out that a shellfish grant should be near a good market. In this day of almost universal high demand and efficient transportation perhaps this requirement is not as important as it was shortly after the turn of the century, but it is certainly a point to be kept in mind. Where are you going to sell your crop?

There is an element concerning control and protection of your chosen site. Is it close to your own home, or, alternately, is it where you can keep it under constant surveillance? While most states have laws dealing with piracy or thievery – and pretty severe penalties in some cases – there can be no protection quite like being on or overlooking your own grant.

Depending on the type or types of shellfish you are planning to grow, is the soil proper? Not all shellfish thrive under the same conditions. Or, if it is not exactly right, can the bottom be converted inexpensively and with relative ease? (The most

Cross section schematic of an ideal multiple-crop grant area.



advantageous soils will be discussed separately with each kind of shellfish.)

If you are going into bottom culture, how long does the tide cover the area? Too short a time and your stock will be slow to reach a marketable size because of too short a feeding time. Too long a tide cover and your harvesting (unless you are going into hydraulic harvesting) will be more difficult. If you are going into hydraulic harvesting, have you enough water to work a long tide? In rafting you will need to have enough water to float your trays or strings even on extremely low tides.

There is no question that the growth of shellfish is in large measure determined by the availability of the proper food, and since the current or tide flow brings in that food, is there sufficient circulation of water so your crop will grow quickly? Another function of the current is that it will remove wastes which the shellfish have passed off. There comes a fine point here between sufficient current to bring in food and carry off wastes and too much tide run so as to cause silting (which can be deadly), or, for want of a better term, current erosion. The chances are that if silting or current erosion did not exist before you planted your shellfish, it will not bother afterwards, particularly with the burrowing shellfish, quahogs and clams.

A third benefit of good circulation is that it will bring in adequate oxygen. Even as they require a plentiful supply of food, shellfish must also have enough dissolved oxygen. And while it is true that a broken surface of the water tends to aerate the water and thereby bring in more oxygen, care must be taken the water is not rough enough that wave erosion disturbs the bottom greatly or that suspended trays are thrashed back and forth, unsettling the growing shellfish there.

It almost goes without saying, stay away from polluted areas. Stay away from areas where there is even an apparent danger of pollution. It would be heartbreaking to work two or three years only to find your product was unsalable because of pollution.

There is one other type of erosion beyond that caused by wind and tide, that caused by ice – either by its movement, or by water running under ice sitting on the bottom. Too, there have been known cases in Cape Cod Bay where oysters were transplanted by freezing to ice floes as the ice rested on them at low tide and drifted off on high tide. I suppose it's safe to say the more exposed the water, the further north, and the colder the winter, the more danger there is of erosion of this sort. In rafting, hopefully a relatively enclosed body of water will see less ice shifting than in more open water. Rafts can be sunk by ballasting them with sandbags during the winter, but it is a messy, time-consuming chore.

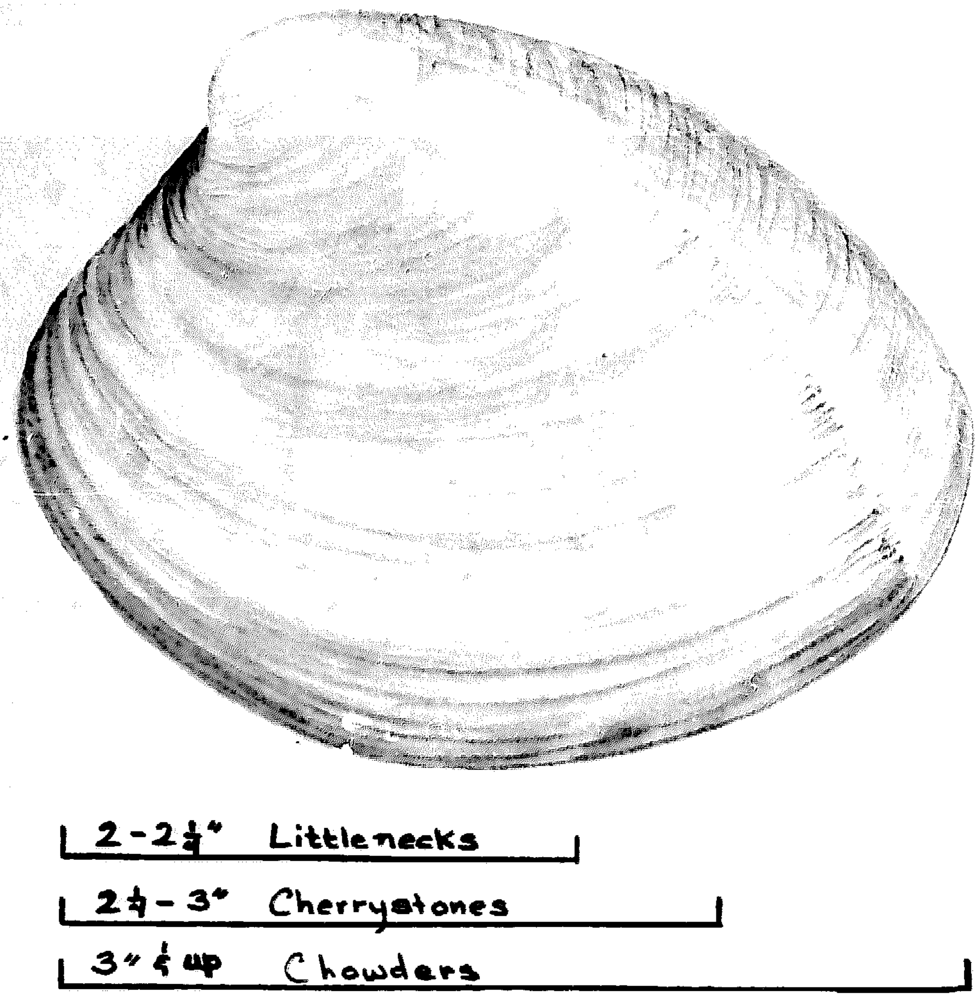
So the elements to watch out for in choosing a site are: a known productive area, easily accessible, with the proper or adaptable soil, protected from erosion by tide, wind and ice, in a depth of water suited to your type of aquaculture, with sufficient tide and no danger of pollution.

2 QUAHOGS

DESCRIPTION

There should be no need to introduce the quahog to anyone living along the Atlantic seaboard, since it grows from Nova Scotia to Florida with some unexplained gaps along the way, in sand or mud, in depths varying from the intertidal zone to fifty feet. True enough, it is known by a variety of names: "clam," "round clam," "hard clam," and "chowder clam." To compound the confusion, quahogs from two to 2¼ inches are called "littlenecks," or "littleneck clams," and quahogs from 2¼ to three inches, "cherrystones," or "cherrystone clams." The littleneck-cherrystone designation is an arbitrary commercial size device, varying with supply and demand. (And, of course, in states having a 1½-inch legal minimum, as Rhode Island and Connecticut, littlenecks will be even smaller than in Massachusetts with a two-inch minimum legal size.) To add to the variety, New York measures the thickness instead of the length.* If

*From "Proceedings of a Workshop on the Shellfish Management Program in New York State: (a) clams [quahogs] one inch in thickness or larger but less than one and seven-sixteenths inches in thickness, shall be called 'necks.' (b) clams one and seven-sixteenths inches in thickness or larger, but less than one and five-eighths inches in thickness shall be called 'cherries.' (c) clams one and five-eighths inches in thickness or larger shall be called 'chowders.'



Quahog sizes to scale: "littlenecks" 2-2¼ inches
"cherrystones" 2¼-3 inches
"chowders" 3 inches and larger
These sizes are arbitrarily set by demand in Massachusetts (by law in New York) and may vary in season.

quahogs are in short supply, it may be that littlenecks will run as large in the market as 2¾ inches, and cherrystones to 3½ inches.

Anything larger than a cherrystone is either just plain quahog or chowder quahog. Commercial fishermen are apt to make one other division: an old, tide-and-sand-worn specimen may be called a "blunt," and a younger, even though larger, quahog, a "sharp." The point is they are all the same animal though called by different names in different sizes and places.

A search for a concise description of the quahog, one which steers away from Latin terms, is frustrating. One authority says it is so well known there is no need to describe it, another that the shell is large, thick, solid and rather well inflated. Dr. Belding described it: "The quahog shell is formed of two heavy valves [shells], equal in size and curvature, which enclose the soft parts and may be drawn tightly together for protection . . . . The shell of an adult quahog measures slightly more in length than in width."*

It may seem strange that with the wide range both geographically and environmentally, natural quahog stocks are in danger of depletion, but apparently the only method of permanently increasing the supply of quahogs is by aquaculture. The methods of harvesting quahogs are not at all efficient, the price has risen nowhere near the level of more exotic seafood such as lobsters and scallops, and quahogs do, under the right conditions, grow fairly rapidly.

GROWTH RATE

This last fact, their rapid growth, plus their relative hardiness, is the element that makes quahog farming attractive, offering relatively quick returns from small capital investments.

"Under the right conditions." As with all shellfish, the growth rate of quahogs is directly proportional to the amount of food consumed. Shut off the tide flow with a bed of eelgrass or a man-made fence, alter the channel and adjacent bars and thus restrict the amount of water flowing over feeding quahogs, and the growth rate slows, sometimes so much that it will take four times as long as normal for a quahog to attain marketable

*Dr. David L. Belding: *A Report upon the Quahog and Oyster Fisheries of Massachusetts,* originally published in 1912 for the Massachusetts Department of Fisheries and Game, Boston, Massachusetts.

size. Certain elements in some bleaches will destroy much of the phytoplankton, a normal food, and quahogs thus deprived may take six or seven years to reach a legally marketable size. (The same elements may even literally cause clams to starve to death.)

Normal growth starts when the water temperature warms up to near fifty degrees. In the Cape Cod area this is usually before the first of May. Most years, growth slows and comes almost to a stop in November, when the water temperature falls below forty-five degrees. Growth is most rapid under natural conditions during the second year. Quahogs appearing visible to the naked eye in July or early August the first year may attain a size of slightly more than half an inch in the part of the year remaining. Quiet, almost dormant during the cold weather, they start to grow again when the water warms, and in natural conditions, in two more years should reach littleneck size. After that, the growth rate slows, and it may be as much as four years more before they reach chowder size – a great deal longer, of course, if the tide flow is inadequate or they are set high in the intertidal area, and thus covered by food-bringing water for too short a time.

IMPORTANCE OF CURRENT

Again, the importance of the current should be stressed. Not only does it bring food and supply oxygen, but it also brings lime salts to build the shell. It is a well-known fact among commercial fishermen that fast-growing quahogs (and clams, too, for that matter) will have very tender or brittle shells, whereas slow-growing quahogs will have much thicker, heavier shells. The former case indicates the supply of food has outreached the supply of lime, whereas in the latter case the opposite is true.

But the current should not be so strong as to bring in silt. Silt will limit the feeding time, and if it builds up around the quahog, it will force the animal to exert itself "climbing" above the silt. In extreme cases, silt can completely bury and smother both quahogs and clams.

One other function of current: it will carry away waste from a heavily concentrated bed and thereby help reduce the danger of contamination.

If the quahogs on a grant are to be harvested by hand, there must be a decision made as to where they are best planted in relation to the tide rise and fall along the beach. Unlike clams, because of harvesting methods, they are better grown below the average low water line. The length of time they can feed is then extended to the maximum, and there is less danger from exposure during the winter, both from freezing and ice erosion. Quahogs growing in ground exposed to freezing temperatures will usually survive if they are thawed naturally, as when the tide comes in, and most years in this sort of area, "winter-kill" is at a minimum. But why expose them to this obstacle? As long as the water is not so deep as to make harvesting difficult, they are better off covered at all times than exposed twice a day to a broiling hot sun in the summer and freezing temperatures in the winter.

SOIL

As to the type of soil best for quahogs, they will grow in almost any kind of soil that does not contain organic acid. They have been known to grow in mud almost too soft for clams, and in all the grades in between, up to hard sand and coarse gravel. If you are picking a site or preparing the bottom, a mixture of sand and mud is good, hard enough to be firm, but loose enough to permit easy raking.

With the new techniques of transplanting, beds of fairly coarse aggregate up to an inch in diameter (if the gravel is available and economically feasible) furnish a great deal of protection for the young quahogs, especially from crabs in the summer and birds in the winter.

Surrounding beds of eelgrass are not necessarily harmful, since eelgrass is a detriment only when it becomes thick enough to interfere with water circulation. Similarly, other marine weeds such as sea lettuce are harmful only when they grow or are deposited on the bed in quantities heavy enough to shut off the current flow or to smother the shellfish.

PREDATION

There is bound to be a slight amount of predation, particularly in very young quahogs. Directly after the setting period, when the quahog is barely visible, strong winds and tides can cause trouble. More dangerous, particularly if the ground in which the seed is growing is exposed, are radical changes in temperature or heavy, cold rains. There is not much you can do about that. Some fish will lunch on the barely covered seed. Crabs are very bad, particularly green crabs, since they seem to be showing up in such great numbers. They and blue crabs will feed on quahogs to littleneck size, cracking the little shells and chipping away the edges of the larger ones. And, of course, feeding adult shellfish are cannibalistic where their larvae are concerned, since in effect their own seed becomes part of the zooplankton. (See Chapter 6 for more on predation.)

Particularly in the winter, sea birds, ducks, geese and sea gulls will puddle out juvenile shellfish. If the baby quahogs are too big for the ducks and geese to eat, sea gulls will pick them up and smash them ashore.

As far as adult quahogs are concerned, moonsnails are perhaps the worst predator (at least in these waters). The moonsnail moves fairly rapidly on its very large mantle, or with the mantle partially exposed, it can be carried long distances by the tide. It engulfs the quahog in this mantle and drills a neat, circular, countersunk hole with its rasp, usually through the umbo or hump beside the quahog's hinge.

In some areas whelks are more troublesome than moonsnails, though in proportion to their size they are not as hungry. They wrap the quahog in their mantles and pry open or break off the quahog shell by inserting and twisting the edge of their own shells.

In other areas starfish can be a major problem, though they are more apt to attack juvenile quahogs than larger ones. They wrap their arms about the quahog and apply suction to both shells, eventually pulling apart the quahog's shells, and then inserting their digestive organs between the shells.

So far we have centered our attention on the grant and the pertinent laws, the conditions which are desirable, with some consideration of the dangers (more about coping with them later). A word about bottom preparation. If the bottom is mud or silt, the addition of a "coating" of coarse sand to the depth of an inch or more will not be wasted, although it is not vital. Whether the bottom is mud or sand, most of the rocks and other obstructions should be removed to facilitate harvesting. There has been a great deal of interest lately in cultivating the bottom, either mechanically (if the water is shallow) or hydraulically with a "Maryland clam escalator" if the water is deeper. (In most cases the depth of water regulates the size of the rig.) As to the benefits from such cultivation, it can certainly be said the escalator method will remove most of the dead shells, old bottles, and such trash, but whether or not such cultivation is worth the trouble and expense is open to argument. It is certainly not a sine qua non.

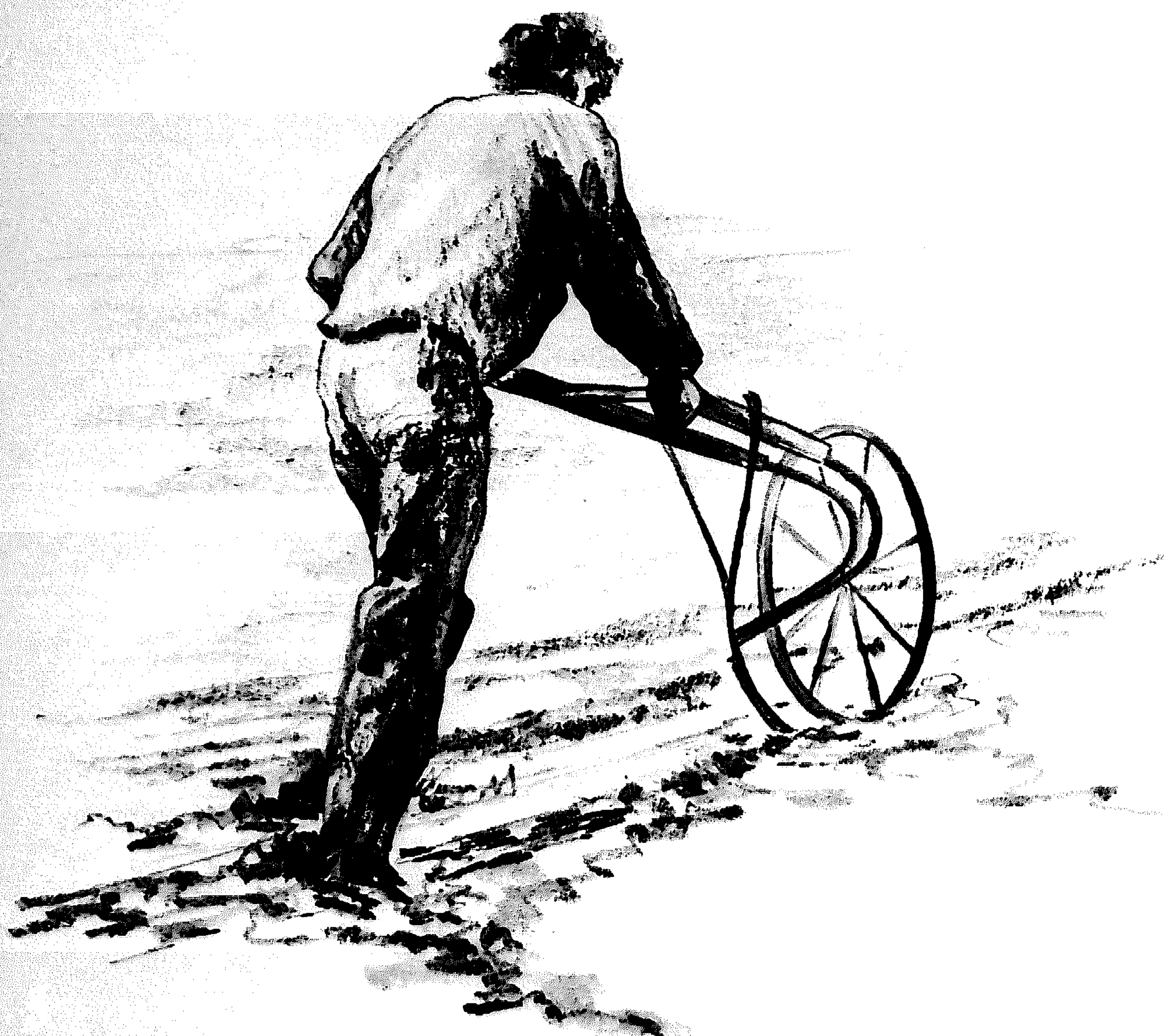
METHODS OF PLANTING

Using Mature Stock

Now to the animal itself and the methods of planting. Hoping for, but not depending on, a lucky, natural set, there are three proven methods. The first is to plant mature stock, adults, readily salable, a reserve until your cultivated stock is marketable. Whether you catch your original mature stock yourself and plant them on your grant by simply spreading them out in an area reserved for them, holding them for an increase in price; or you buy them from the local fishermen when the price is

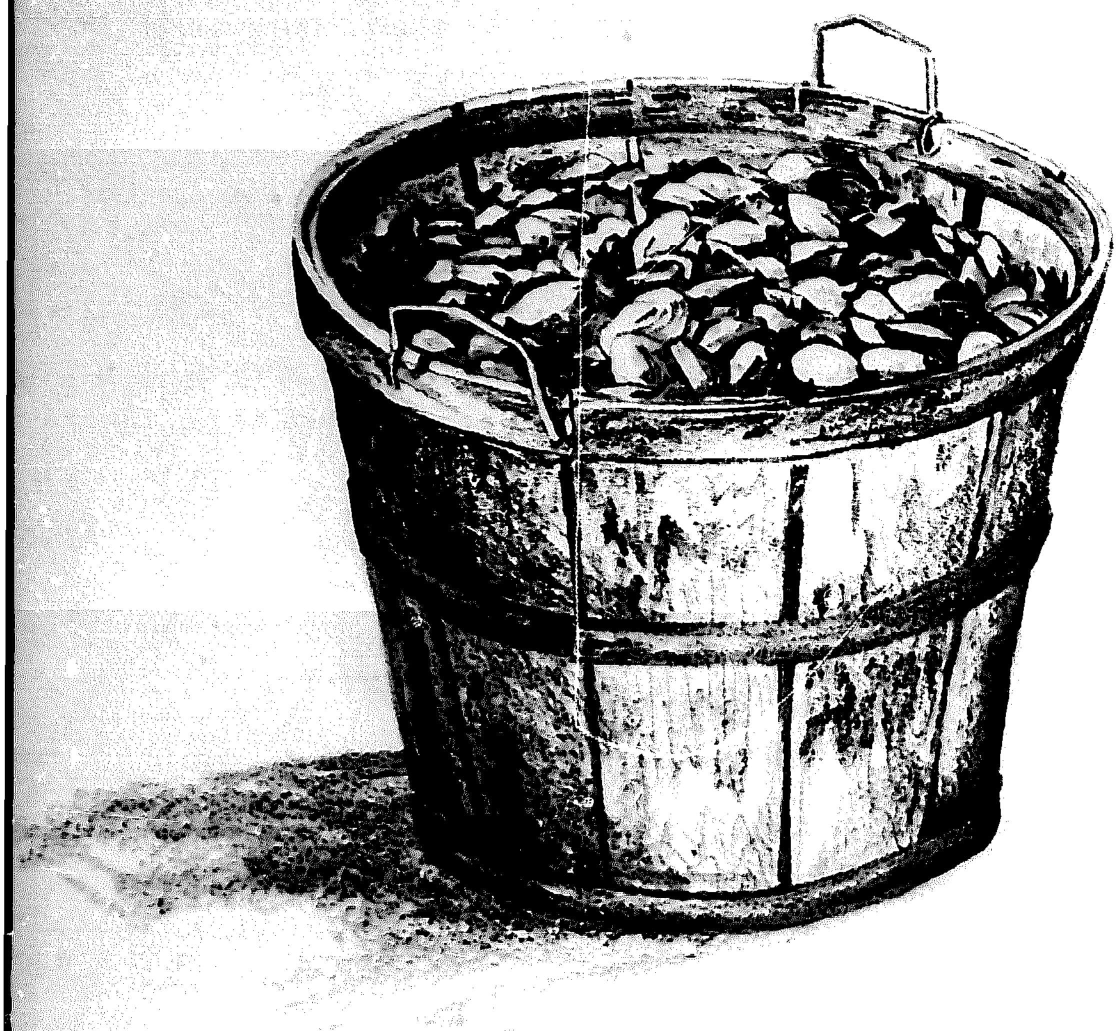
Planting adult quahogs with the tide up. They need only be dropped onto the grant. They will bury themselves where they land.

down, they may be planted much thicker, almost touching, than the stock you are "forcing" to get to market size. You won't expect nor get much growth from this chowder stock, but there should be little loss in transplanting and re-digging, except for some slight breakage. It will pay a day or so after your broadcasting them on the bed (and granting the water is shallow enough) for you to go over the bed, turning sharp side down those quahogs which landed bottom up or are hindered by shells or stones from digging themselves in. Those lying on their sides will probably survive, but they are vulnerable to blue crabs and big starfish and their exposed sides are apt to gather planktonic growth. If adult quahogs are crowded when planted, predation will be at a minimum and their very closeness will



The farmer takes to the shore. Special care should be taken with the plowshare when transplanting clams: the foot must be parallel with the ground and the mold board must be pitched enough to cover the previous furrow.

make for easier, quicker harvesting. There is always the chance, somewhat improved by previous cultivation and by planting before the spawning season, that the millions of spawn may settle on your grant and give you adequate seed to grow. It's slim but it's there.



A full bushel of soft-shell clams for transplanting for growth and/or spawning stock.

Using Immature Stock

The second method is to buy from a hatchery or dealer immature stock, perhaps an inch or so in their longest diameter, that is, quahogs in their second year. In this kind of transplanting in the spring or early summer (not before the water has warmed and the quahogs have become active) you can expect a slowing in the growth rate for a month or so because of the transplanting. Stocking your grant this way may be fairly expensive, but it is fundamentally what oyster growers have been doing for years, and the method currently most successful in clam planting. Try with all shellfish transplanting to do it when air and water temperatures coincide as nearly as possible, thus avoiding unnecessary shock.

It is best, because of the danger of silting, not to plant this size quahog in screened trays or boxes on the bottom, nor fence them in with fine screening to keep off predators, nor again under sheets of fine netting where there is any appreciable tide flow. Certainly, if you feel you must plant, using trays, screening, or netting this way, remove the obstructions before winter sets in and the ice removes them for you. These techniques are expensive, difficult to maintain, very likely to cause silting, and will slow growth because they will shut off the flow of water, the essential tidal circulation. (This prohibition is not to be construed as including fencing put around an entire area to keep out green crabs, though such fencing should be cleaned of grass and marine flotsam occasionally as needed.) It will prove to be an advantage to plant this size quahog in relatively coarse aggregate, preferably in beds which are built up slightly, an inch or so, above the bottom level. This type of planting is more expensive initially, but will provide a much higher rate of survival and probably a faster rate of growth.

This is a "cold frame" situation. You, or the hatchery where you bought your seed, correspond to the "hot house." Moved during the second year to the cold frame, the quahogs are then ready for their final growth in the garden.

To get the sort of aggregate we wanted, we sieved ordinary shore gravel through one-inch mesh wire screening to get out the rocks. Winter survival, if the quahogs are exposed above low tide line at all, is perhaps as much as twenty percent higher if the natural sand is left in the gravel, rather than when the sand is sieved out with fine screening. Weighing initial cost against the cost of labor, commercially screened, 3/8-inch "pea stone" may be substituted for natural gravel where it is available and not prohibitively expensive.

Adult ("Chowder") quahogs by the 80-pound bushel, to be held on the grant for a rise in price and/or as spawning stock.

Rather surprisingly, little quahogs no bigger or not as big as the gravel will work their way down into the sand below. (We made our beds about two inches high initially, though they flattened out somewhat the following year.) There the juvenile quahogs are protected from most predators including crabs, and, if in shallow water, from puddling geese and gulls.

Rafting With Seed

The third and most profitable method of raising quahogs (at least so far as survival goes) is to buy your seed, five to ten millimeter quahogs from a hatchery, and to suspend it in trays from rafts. The size of the rafts, usually made with Styrofoam for flotation, is dependent, of course, on the size of the trays and the depth of sand, or sand and gravel, in the trays. While some of the trays involved in this kind of culture have been built as large as twelve by twenty feet, using four ten-foot logs of Styrofoam, we have found that a much smaller tray (see specifications following) was easier to handle, and only a little more expensive to build, square foot by square foot. We also went through the "putting too many eggs in one basket" routine. There's this about it: if you lose a single small tray, perhaps by its being smashed by the ice, you've lost maybe 5,000 baby quahogs. If you lose one of the big ones, you stand to lose as many as 60,000.

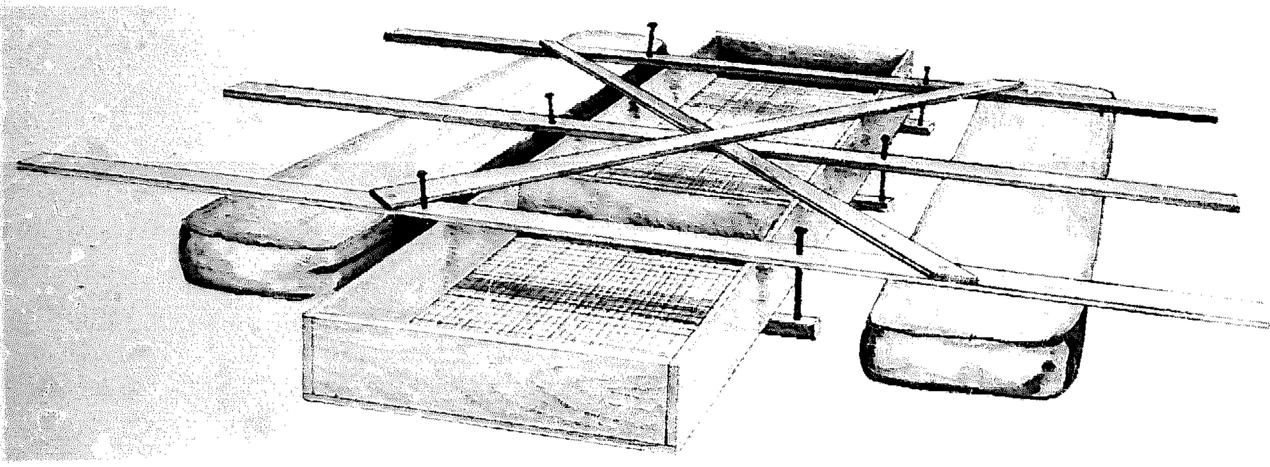
There is another point here. While one grower, using the larger tray, is piling in 60,000 seed quahogs, we have found a much better growth rate by refraining from overcrowding. Research says not more than seventy-five per square foot; we have more than doubled that concentration successfully since we have a very good tidal circulation of water and an obvious abundance of food.

RAFT AND TRAY CONSTRUCTION

Following are specifications for materials and directions for building raft and tray.

For one raft:

- Two Styrofoam logs, 10 feet x 24 inches x 8 inches (Smaller logs will get you by, but the extra flotation is a safeguard.)
- Five 8-foot 2 x 6's



Detail of raft and tray ready for half filling with sand and/or gravel, and the planting of quahog seed. A similar setup may be used without the sand and gravel to "raft" juvenile mussels or oysters.

- Two 10-foot pieces 1 inch x 3 inch strapping
- Six 12-inch x ½-inch carriage bolts (galvanized)
- Six nuts and washers for above

For one tray:

- Three 12-foot 2 x 8's
- Three 4-foot 2 x 4's
- Three 12-foot pieces 1 inch x 3 inch strapping
- One piece 12-foot x 3-foot vinyl-covered 1-inch mesh screening
- One piece 12-feet x 3-feet vinyl-covered 2-inch mesh screening (or a reasonable substitute. Use only if needed to keep out fish predators, blowfish, sculpins, tautog, etc.)
- Thirty-six square feet plastic window screening
- Six 20- to 24-inch x ½-inch galvanized through-bolts or carriage bolts
- Nuts and washers for the above
- Nails and staples, mooring and rope.

To build the float: center a 2- x 6-inch plank under each log, lengthwise. Crosswise, bolt the other three 2 x 6's (one in the center and one a foot or so in from each end, bringing the crosswise planks' ends flush with the outside edge of the logs) through the crosswise planks, the logs, and the lengthwise planks. The 1- x 3-inch strapping may be nailed diagonally from corner to corner to stiffen and prevent the whole raft from twisting.

To build the tray: a frame is made of the 2- x 8-inch planks on edge, measuring 12 feet x 3 feet on the outside, and divided into three sections with the remaining pieces of 2 x 8. To this frame is stapled the 12-foot x 3-foot 1-inch mesh vinyl-covered wire. All of the edges, as well as the crosspieces, should be covered by nailing on the strapping over the staples. Turn the tray over and line the inside bottom with the plastic window screening, stapling it sufficiently to keep it from shifting.

Now move the tray to the water's edge at low tide, and under the float or raft. The three 2 x 4's should be placed under the tray and under the crosswise 2 x 6's. The through-bolts or 20- to 24-inch carriage bolts should pass through the 2 x 4's as close to the trays as convenient and through the crosswise 2 x 6's.

USING THE TRAY

Into the tray, load soil to the depth of about 4 inches. When the tide has come and gone a couple of times to settle the soil, the tray is ready for the quahog seed. In a comparison of soils, we have established that the rate of growth of the seed may be much more rapid when either crushed (3/8-inch) pea stone or "native," sifted, beach gravel of about the same size is used than with sand, or a mixture of sand and gravel.

With the tide in and the whole rig floating, spread as evenly as possible upwards of 5,000 5- to 7-millimeter quahogs. (They will not be crowded even if held to littleneck size.) They will work themselves down almost immediately. Across the top you may want to staple the 2-inch mesh vinyl-covered wire, or a plastic substitute to keep out hungry fishes. If the danger of fish predation is small, do not use the wire on top, as it tends to gather planktonic growth and thereby shut off the flow of water, food, and oxygen. Secure the mooring, and the rig is in operation.

There arises the question of antifouling paint on the wooden parts of the tray and raft. This will have to be governed by local conditions. If teredos or ship worms are plentiful or even common, the wood will have to be painted with some antifouling paint. If, on the other hand, there is little danger from teredos, there is a much greater chance of your catching native seed in the unpainted trays. This is particularly so with trays painted with copper-based paint, since this type is specifically designed to kill, or at least discourage, marine organisms. A sort of compromise may be reached by painting your underwater wood with fiberglass resin.

ADVANTAGES OF OFF-BOTTOM CULTURE

The advantages of this kind of off-bottom culture are at least twofold. The first is that it is almost completely predator-free. With the exception of possible fish predation, none of the usually destructive animals can reach the suspended shellfish. Comparing companion plantings, off-bottom and in naturally productive bottom, with 5- to 7-millimeter quahog seed, for one year, the mortality on the bottom was at least ninety percent, while off-bottom mortality was seldom over ten percent.

The second advantage is the rapid growth, particularly in the trays containing gravel only. In one experiment, seed quahogs averaging 7 millimeters and planted in gravel in May had reached littleneck size in fifteen months, a phenomenal growth when compared to natural stock, bottom-grown, which took the setting summer and two more full years to reach marketable size – this in the same body of water.

This extremely rapid growth gives rise to an economic problem: when to move the quahogs out of the tray. Which is more profitable: to hold the growing quahogs off-bottom until they have reached market size – and thereby prohibit the further use of those trays the rest of the second year, using a duplicate set of trays for the second year's seed; or to move them to the field, and thereby delay the final growth of near-littlenecks, so the trays may be ready for a second year's crop? In the latter case, survival will be higher if transplanting is done in the spring, rather than the first fall, though winter care of the rafts and trays may counterbalance economically in favor of a fall transplant. These problems, I think, create a dilemma the grower will have to solve, and will be governed somewhat by the size of his capital and the local conditions. The mortality in any case should not exceed thirty percent of the number of quahogs handled.

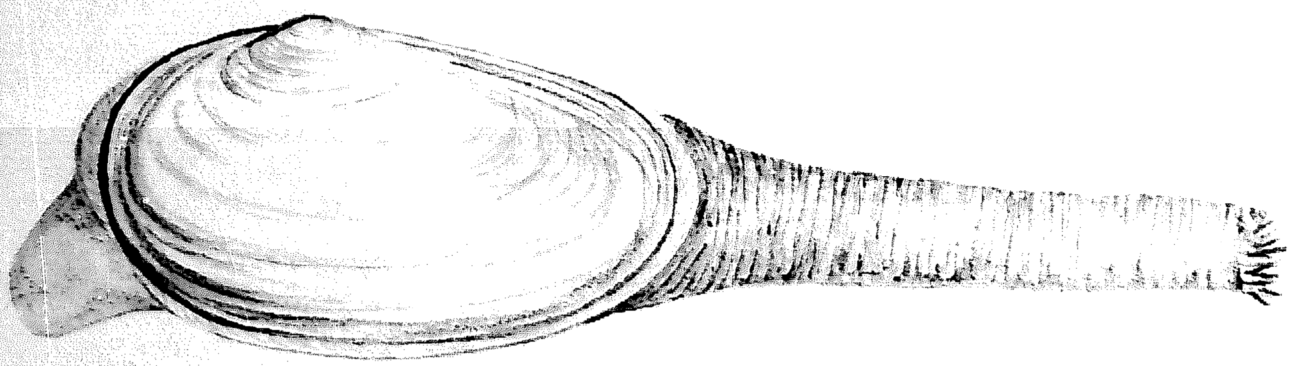
Since experiments in quahog culture are being carried on in a number of places, it is very possible that by the time this gets to print, there will be new refinements in the methods described here, particularly in off-bottom culture, and possibly new methods discovered. Quahog culture has several factors to recommend it. Quahogs are relatively hardy and will grow under a wide variety of conditions; both adult and laboratory-spawned stocks are readily available; and the demand is stable, season to season and year to year.

3 CLAMS

RANGE

The most heavily fished, usually hand-dug shellfish on the east coast of the United States today is the soft-shell clam, called also "long clam," "long-necked clam," "steamer" or "steamer clam," and "piss clam." It grows from the Arctic to South Carolina, though it is scarce south of Cape Hatteras. Delaware and Maryland (where much of the harvesting is now being done by hydraulic escalator) ship quantities of clams out of state. Maine is a major producer, while most of the Massachusetts clams, though raised all along the shore, are grown in the Ipswich area, thus the occasional trade name of "Ipswich clams" for all soft-shell clams, no matter where grown.

Clams grow in protected waters, in sand, mud, or even gravel. In Massachusetts they are found chiefly in the intertidal zone, though elsewhere they may grow in deeper water.



Soft-shell clam with neck and digging foot extended.

DESCRIPTION

The two elliptical shells, about twice as long as wide, are hinged at the back, and do not close tightly at both ends as quahog shells do. The shells are fragile (the more so when grown rapidly in sandy soil) hence the name soft-shell clam. The shells may vary in color from white to black, since they take on the color of the soil in which they grow. If grown in gravel, clams may have very rough shells due to their environment.

DESIRABLE CONDITIONS FOR PLANTING

Clams grow chiefly from May to November, and continue to grow slightly even when the water temperature is as cold as forty degrees F. They may grow to reach an inch in length their first year, and reach two inches or more during their second summer, under optimum conditions. The third year may add another half inch, and so on the fourth year. This rate of growth, of course, is dependent on good growing conditions and a long season.

A fair exchange of water is necessary to bring adequate food, but an excessive tide run may cause shifting sand or bring in silt, which makes it difficult for the seed to set and for the adult clams to grow. (In choosing a grant site it may be well to remember that, while the current may be swift in the channel, it is not necessarily as strong along the higher tide lines, and therefore not as inclined to cause tide erosion or shifting sand.)

Water in motion carries more oxygen than still water, and since adequate oxygen is essential to clam growth, good circulation is important. Furthermore, moving water will tend to carry away unwanted wastes.

Clams cannot grow on exposed beaches, as they will have trouble with shifting sand. (Although shifting sand will make it impossible for seed to set, larger clams can cope a little more successfully.) Slimy bottom will prohibit the setting of clam seed, and soft mud containing hydrogen sulfide or other organic acids caused by decaying vegetation will prohibit growth and erode shells.

In choosing a clam bed site you can test for acidity with litmus paper or with an ordinary soil-testing kit, sold in many hardware and gardening stores. You can reduce the acid condition by cultivation (harrowing or turning over the bottom), either hydraulically or by mechanical means. Subsequent resanding to an inch or so in depth will help and will provide better material for very young clams to cling to. Do not use "polished" beach sand, but get "sharp" sand from the local sand pit, screening out the coarsest of the gravel. Beware of rusty, red sand; your clams will probably grow in it but the color of the shells will do nothing to enhance the sale of your product.

Eelgrass will do nothing to improve your bed. If it does grow on the bed it will make for difficult digging, and if it grows to excess around the bed it will tend to cut off the flow of water and might even cause silting, which could in time raise the level of the flat.

While they may catch some spat, mussels growing on a clam bed will eventually ruin the bed because they will decrease the food supply. They are also apt to deposit an excessive amount of silt, as well as organic acids harmful to your crop.

You should, of course, be very careful to avoid manufacturing wastes and pollution. Because clams feed more rapidly than other mollusks, they are very susceptible to these elements. There is some evidence that certain elements in some bleaches kill phytoplankton, an essential food. Therefore, beware – there is no laundromat at the head of the creek you are selecting as a site to raise shellfish. Interestingly, clams are more tolerant of changes in salinity than oysters. They can be transplanted from highly saline areas to almost brackish water or vice versa without apparent ill effects.

Spawning time varies according to location. It usually takes place while the water temperature is between seventy and seventy-four degrees, which means, in the Cape Cod area, primarily a three-week period in June and July. But this is not a hard and fast rule, particularly with a warm fall in Cape Cod and areas south, where a second spawning may occur as late as September.

Predation and Other Dangers

When the natural dangers confronting microscopic clam seed in its early, free-swimming, period are considered, it is a wonder that any survive. It is at the mercy of tide and wind; cold rain can kill it; it may be washed up on an inhospitable shore; everything in the water eats it: fish, worms, crustaceans, even other shellfish. But after a few weeks, the survivors put down a foot, grab a grain of sand, grow a shell, and bury themselves. It is still prey to many predators. Moreover, a heavy wind may shift the sand and smother it, or the tide may wash it out. Then, as it grows bigger, it is faced with a whole new set of enemies.

Waterfowl – gulls, diving ducks, and Canada geese – are particularly bad in some areas. Fish, flounders, tautog, eels, and even striped bass will dig clams out, for we have examined the stomachs of these fish and found quantities of juvenile shellfish, including clams, in them.

Young starfish are particularly destructive of young, hardly-buried clams, and oyster drills, too, will occasionally attack baby clams. As they grow larger, moonsnails become a particular enemy, a two-inch moonsnail eating as many as a clam a day. Horseshoe crabs will rootle them out, crushing some and eating others. Blue crabs will eat them, and in some places green crabs have destroyed entire sets. It is the protection given against this host of natural predators which improves the clam's chances for survival and makes farming them profitable.

Location

There now arises the question of the location of a clam grant. The requirements are somewhat the same as for a quahog grant. As extra insurance, you could transplant a few clams to the area of your choice and watch them grow, but it's not necessary. If any clams grow there, showing a reasonable growth per year, you can probably use the area, improve it, protect it, and maintain it successfully.

It should be easily accessible if possible, preferably where you can watch over it at low tide, whether from your home or from a handy vantage point. It should be protected from tide and wind erosion, but with an adequate circulation of water to bring in food, lime salts (the element in salt water from which all shellfish build their shells), and oxygen, and to carry off waste matter. It must have a minimum danger from present, and, so far as possible, future pollution. The danger of moving ice or freezing in winter will not be as vital as with quahogs, since the clams will be deeper in the soil.

But here the similarity ends. Unless you plan to harvest your clams hydraulically, as is done in Maryland, for example, you are going to need the biggest part of your grant between the tide lines, in the intertidal zone. Now you are caught in a bind. You will want your clam bed covered with water as long as possible for more rapid growth, but you will want them exposed for a reasonable amount of time, so you will have a longer tide in which to dig them when they are ready for market.

In planning a clam grant, under the new law in Massachusetts concerning dredging and filling of wetlands (Chapter 131, Section 40), there is a chance to reclaim a non-producing area, thereby creating an ideal situation. The law says, in part:

"Any person who shall remove, fill, dredge or alter any . . . wetland . . . shall file a written Notice of Intent . . . with the Conservation Commission, Massachusetts Department of Natural Resources and Massachusetts Department of Public Works, together with a filing fee of $25, payable to the city or town in which the area is located . . . work [may] be performed for normal maintenance or *improvement of lands for agricultural use*." (Italics mine.) "Agricultural use" in this case may be interpreted as "aquacultural use."

The possibilities here are endless. In many areas sedge grass has encroached on areas which formerly were productive. The simple removal of this grass by dragline or bulldozer is, in many cases, all that is necessary to create a new clam bed or renew a former one. If the bottom is too soft when the grass is removed, the spreading of several inches of sharp sand and a settling period may be needed.

In some areas the sedge grass removed will have to be carted off, which will run up the cost somewhat. Recently (November 1975) we engaged in this sort of project. Cost for approximately ¼ acre:

Dragline @ $140.00 per day for 2 days	$ 280.00
3 trucks @ $120.00 per day each, for 2 days	720.00
Total cost	$1,000.00

ACQUISITION OF SEED

The acquisition of your original seed is going to be a problem. Very few localities have enough clam seed that they are going to want you mucking about "thinning out the seed." Massachusetts grant holders, as long as the two-inch minimum size limit holds, are in a better position than those in some other states, because they can buy "short" (by Massachusetts standards) clams in either Maine or Rhode Island (assuming they have first obtained the necessary permits from the Department of Natural Resources, Division of Marine Fisheries). On a short-term basis this can work out very well. One-inch to 1¼-inch clams, transplanted to good growing ground in April in Massachusetts, may be ready for digging by September. If the market is poor then, they will grow very little before next summer's rising market.

Going by Dr. Belding's tables of number/volume* and allowing 100 percent survival, the one-inch clams you planted will increase eightfold, and the 1¼-inch clams fourfold. You can't expect 100 percent survival, of course, but even a fifty percent survival will give you a pretty quick return on your investment, and you ought to be able to expect seventy-five percent or better survival.

PLANTING METHODS

If there is local clam seed available, this year's or possibly last year's set, clams from ½ to one inch long, they will be fragile. There are two practical methods of taking them up. The first is to sweep or wash them manually into a sort of scoop. We built a scoop of ½-inch cellar window wire, as wide as we could straddle comfortably (about two feet), about six inches high, and 2½ feet long. This was stiffened by an enclosed framework constructed either from secondhand electrician's tubing or deformed iron reinforcing rod. It was raised slightly off the ground with short, sturdy legs, and had an apron about a foot long and several inches wider than the box on each side. This scoop, used underwater, is put down near the clam seed, facing up against the tide. Clams, sand, and all are thrown back into the scoop with a wide-tined clam hoe. We found it best not to take too big a bite each time. When a strip clear across the apron had been thrown back, the scoop was hitched forward and the operation repeated. The running tide should carry off a good

* *The Soft-Shelled Clam Fishery of Massachusetts*, original 1916 edition reprinted by the Massachusetts Division of Marine Fisheries, page 30, Table 4.

part of the sand. What is not washed through may be sieved out by rocking the scoop on its after legs. This works fine in sand but is not so efficient in sticky mud.

The second method is to build and use a siphon. We used a foot-long piece of three-inch copper tubing, a ninety-degree elbow, tapped for one-inch pipe in line with the middle of the outflow, and a two-foot piece of the same tubing for the outlet. The pipe let into the back of the elbow was extended facing the middle of the outflow and halfway across the inflow or suction end, and the whole was brazed or soldered together. To this we coupled the outlet hose of a gasoline-powered, centrifugal pump rated at 250 gallons a minute at fifty pounds pressure. (Our first experiments with a pump half the size were not successful.) At the outlet end either an onion bag or similar fine mesh bag was secured, or else we simply pumped into the scoop as described above. This method, while obviously much more expensive initially, is far more efficient than the scoop if there is any quantity of clams to be moved. The suction created is great enough to lift three-inch quahogs, and there seems to be no reason it should not be used to harvest adult clams, although there are local regulations against its use in some areas. (The reason for the prohibition seems to be that no one is sure what effect the radical shift of bottom will have on future clam sets, though we have used it for some time with no apparent ill effects.)

Hatchery clam seed, unlike most other shellfish seed, is, to my knowledge, seldom available at this time, probably because handling very small clam seed is a tricky business, and holding clam seed until it is big enough to transplant is expensive. However, if small clam seed is available and is handled carefully (and, if possible, planted the same day it is taken up), the returns can be enormous – as much as sixteen for one – according to Dr. Belding. Very small clam seed, less than an inch long, is probably best planted by broadcasting it in shallow water, preferably on an incoming tide that is not running too strong. If the clams have been taken up on an ebb tide or on low water, the following flood tide is the best time to plant. (For some unknown reason, very small clams bury themselves more quickly on flood tide than on ebb.) Spread them as evenly as you can, probably not more than fifty to the square foot for maximum growth. Unless the bottom is very hard, the baby clams should have buried themselves in less than ten minutes. There may be some movement afterwards. Young clams have the ability to move about if they don't like their quarters. They are much more mobile than older clams, partly because of their smaller bulk, and partly because their digging foot is proportionately much bigger than that of a mature clam.

Larger clams, especially stunted clams which have grown slowly because of inadequate water circulation, or because they set too high on the flat and were covered for only a short time during the tide, are much easier to handle since their shells are relatively hard. They can be successfully plowed under with a hand-operated wheel hoe.

This sort of controlled clamming would seem to be ideally suited to some parts of the Maine clam-producing areas which are rich in stunted clams which have taken four, five, or even six years to reach a length of from one to 1½ inches. In the slack season, with the price half that of the peak summer season, the aquaculturist could put in part of his digging time in transplanting to his grant, an area known to be fast-growing. A transplanting of this sort, done in the early spring, could pay off generously before fall, or certainly the following summer. In time, the entire operation could be changed to digging stunted clams in the off-season and harvesting the transplanted stock for top prices.

If the necessary permits are forthcoming, clams from contaminated areas can be similarly cultured without danger of spreading the contamination, since the great majority of waste in the water is produced by man. (It is my understanding that this kind of operation – moving shellfish from contaminated to clean areas – has been done extensively in New York, and was done in Massachusetts with oysters while they were still available.)

The first experiments in "plowing under" were done with a horse-drawn, landside plow and were very disappointing. Buried too deep, the clams smothered; in addition, some of them were planted upside down and couldn't right themselves. Altogether, it was a very disappointing method. But if the furrow is made no more than an inch deep with a hand-operated wheel hoe, clams may be poured in from a bucket or coal hod (the most satisfactory container) and covered with the next furrow, just enough so they are largely protected from the first predators which come along. (Very often these will be minnows coming in with the flood tide.) The clams will move about less than they would if they were exposed, and within a week will have dug themselves down to the depth at which they were dug originally. In parallel plantings, inch-long clams planted by broadcasting suffered almost a fifty percent mortality, whereas in an adjacent area, clams were plowed under and had less than a ten percent mortality due to the planting.

Ideally, seed clams should be moved when the water and air temperatures are about the same so they do not suffer the shock of sudden temperature changes. This makes for late spring and early fall plantings. (Incidentally, as a helpful hint, the bigger the diameter of the wheel of the hand plow, the easier it will be to push it on the flat. Also, the plowshare should be cut off parallel to the ground rather than pointed, as it is usually manufactured.)

If you are not cramped for space, plow four or five furrows close together, skip a couple of furrows and repeat. This way the whole planted row can be straddled while digging, and no clams will be covered as you dig. Watery sand will cause problems, because if water gathers in the furrows as you are planting, the next furrow will tend to wash out the clams already spread for covering.

Raised beds can be made of sharp, new sand, specifically for clam planting, either simply rounded off or confined by baffles constructed of 2 x 6's secured to stakes driven into the soil. This type of bed will probably raise clams faster than a level bed, but it is questionable whether or not this type of culture is economically feasible.

If clams are planted below low tide mark, they will have to be broadcast (again as evenly as possible), and then harvested, with either a clam escalator or some other sort of hydraulic rig. Otherwise, they may be brought to the surface of the soil with a plunger (a plumber's helper) or jetted out and scooped up with a basket scratcher. Be careful in jetting out clams in cold weather when they are relatively dormant, as they may fill with sand and be unable to clean themselves.

Predator control on an intertidal bed should be relatively simple and inexpensive during the ice-free months. A simple fence built of one-inch mesh, galvanized chicken wire (or possibly a similar plastic fence which would be more durable and ultimately less expensive), surrounding the bed, stapled to 2 x 4 posts, buried three or four inches at the bottom, and curved over, out and down at the top will exclude almost all the moonsnails and whelks, all the horseshoe crabs, and will discourage both blue and green crabs. It is a deterrent to gulls and geese (and pirates). Since an occasional crab will swim over the top at high tide, and small crabs will find their way through; and since at low tide the baffled crabs may dig themselves in at the foot of the fence, we have found it profitable to enlist the local youngsters to patrol the fence, encouraging them with a token bounty to pick up all visible predators on the bed itself.

If the screen collects too much floating grass it should be brushed or raked off so it doesn't hinder the flow of water. The fence may have an added, unpredictable benefit – it seems to confine clam seed so a larger than normal set may be obtained.

Other than the fence, clams, particularly small transplanted ones, must have protection from the predation of gulls and Canada geese. Two gimmicks have been used and found partially successful. By erecting five-foot posts and stringing between them four-foot-wide plastic screen, letting the bottom flap in the wind, we have discouraged most gulls, which seem to stay clear of the *shadow* of the plastic. This is not so effective with geese since they work largely at night, so we have resorted to using up all the old monofilament fishline locally by stringing it across the bed, a foot or so above the ground, and two or three feet between strands. Apparently, hitting their wings on the unseen mono scares the birds off. However, it is not a cure-all; if geese are hungry enough, even the mono won't entirely keep them from puddling.

Moving ice, as you might expect, will carry off all these artificial barriers, if you don't remove them first. But on the other hand, predation is slowed almost to a standstill in the winter. Not all areas have the same problems, of course, and those that are especially bothered by ducks and geese will only take a chance on losing their mono by leaving it up until ice covers the whole bed.

There is one other rafting technique you may want to try. It's new; it works in some areas, in others not. At least it gives clam seed far greater protection for survival than in nature. Fill trays such as those used in off-bottom quahog culture, place in them a few adult clams before the spawning season (i.e., in the spring), and wait for nature to do the rest. In some areas the natural set of clams will be surprising. (We have caught as much as a bushel of one-inch clams in a thirty-six-square-foot tray.) In other areas the trays will simply set and collect algae and nothing else. To be honest, I don't know why it works in some areas and not in others, but it should be obvious that more clam seed will be caught if the trays are not painted with anti-fouling, larvae-killing paint.

HARVESTING

Harvesting the clams, digging them by hand, can pose problems. Your grant, like all other tide land, will have good tides and poor. If you have a market which is taking all you can dig on a normal tide, there is no reason, on a particularly good tide, not to dig a surplus and store them in floating wooden slatted or vinyl-covered wire containers for a week or more. Furthermore, it will give the clams a chance to clear themselves of mud and sand. Do not crowd them, and be sure they have a free circulation of water. This treatment will do nothing to improve the clams' looks, and they will grow very little under these conditions.

In marketing, handle your clams quickly, keep them cool, out of the sun, and remember that an honest, clean measure with no broken clams will secure your buyer.

4 BLUE MUSSELS

RANGE

Blue mussels may grow almost anywhere in salt water. Their shells are smooth and elliptical, but pointed on one end, and range in color from dark blue to blue-black. They commonly grow in clusters attached to each other and the host ground by strong byssus threads. No particular type of soil seems necessary, for they grow on rocks, spiles, sand, or mud, anywhere between the tide lines, and beyond into deep water. Occasionally, beds of mussels set on a high bar or flat will build themselves up so high as to be barely covered at high water. On the other hand, they grow far out into deep water and not uncommonly attach themselves to lobster pot warps.

Those beds which build too high eventually kill themselves off. Once a bed begins to die, owing to the fact that a dying shellfish uses more oxygen than a living one, the usual sequence is for the entire bed to die out within a year or two. This leaves a mass of detritus and dead shells which, although traditionally called "mussel mud" and used as fertilizer for carrots and onions, is good for practically nothing, except that occasionally quahog or clam seed will set on such a bed of dead shells.

A clump or cluster of blue mussels. Each individual is attached to the clump by byssus threads.

In many areas, particularly those where the main shellfish crop is soft-shell clams, mussels are considered competitors and a nuisance, if not actually predators, and are deliberately destroyed, sometimes being dragged off into deeper water, and sometimes being carried ashore and thrown into the town dump. In at least one case where mussels were raked off a clam flat into piles, they attracted most of the moonsnails and other predators on the flat, facilitating their own destruction in turn.

In many parts of western coastal Europe, blue mussels, if not the only shellfish crop, far and away exceed all others in value and in the extent to which they are harvested. Yet in this country, until fairly recently, mussels have been used almost exclusively as trawl bait (excepting those eaten by a very small minority of ethnic groups who have always considered them a delicacy).

This picture is gradually changing. There is an ever-increasing market for clean blue mussels, partly, perhaps, because of Maine's major effort to sell blue mussels*; partly because of the ever-shrinking supply of soft-shell clams, for which mussels are coming to be used as a substitute; and more importantly, because we are learning how to handle mussels.

SPAWNING

Mussels spawn in the Cape Cod area from early April until late in September. The seed seldom sets on a mature mussel bed, but rather off to one side where it is protected from both the cannibalistic tendency of the mature stock, and the excessive tide run. Juveniles sometimes seek marine growth such as mermaid's hair, or the back side of a bar bordering a channel. As they mature, they frequently crawl toward the parent bed by extending their byssus threads, attaching to a grain of sand, casting loose the old threads, drawing themselves forward, and repeating the process until they have climbed "back home," so to speak. For some undetermined reason, there are spots where mussels will not set on the bottom, but will do remarkably well in some sort of off-bottom culture.

Natural beds frequently occur on bars so high as to leave the mussels exposed to the air for so long a time that they will take three or four years to reach a marketable size (over two inches).

*See *Maine Mussels* by Reggie Bouchard, Maine Department of Sea and Shore Fisheries (now the Department of Marine Resources), Augusta, Maine, not dated (circa 1973-74).

These natural seed beds could be the source of your mussel seed. In off-bottom culture, with the mussels submerged all the time, it is possible for mussels to grow from half-inch seed to over two inches in the summer, in as short a time as five months, and in the fall-winter-spring season in seven months, given optimum conditions. Allowing your mussel crop to grow to a larger size will, of course, bring you more bulk and thereby more money, but there is an expanding market for smaller mussels because they are thought to be more tender. Check with your local outlet for the most desirable size.

PREDATORS

The byssus threads which bind mussel clumps together will be very strong where there is a strong tidal current, but much less obvious when the mussels are grown in trays. Furthermore, in off-bottom culture there is little mud, pseudo feces (natural wastes), or trash (such as periwinkles and dead shells). Predation will be cut to an absolute minimum.

Of the winter predators in bottom culture, eider ducks and other diving ducks are by far the most destructive, destroying at times entire natural beds of juvenile mussels. During the rest of the year, and with larger mussels, depending on the area (still in bottom culture), moonsnails, starfish, oyster drills, and crabs are the worst offenders. Indeed, so fond are oyster drills of mussels that some oyster farmers deliberately set out clumps of mussels in the vicinity of their grants as bait and a substitute for oysters.

BOTTOM CULTURE

Lacking any native mussels in bottom culture, I know of no way of finding out whether or not mussels will do well in a given area other than by trying a sample planting. In bottom culture, mussels may be spread out to a thickness of several inches below low tide mark, as is done in the Netherlands. Particular care must be taken in this type of aquaculture to remove all predators before planting, and a constant watch must be kept for in-moving pests. The same sort of fence as used in clam farming may be used, but particularly where small starfish and oyster drills are prevalent, there seems to be little protection except frequent handpicking. Rather unexpectedly, barnacles can become a nuisance in the bottom culture of mussels. While not predators in the usual sense, they are benthic competitors for food, and mussels coated with small barnacles are not an appealing product. All things considered, off-bottom culture produces a superior and better-looking product.

ROPE CULTURE

In off-bottom culture there are three common methods, two of which seem practical where moving ice may be a factor. The seed may be caught on suspended ropes as is done in Spain and southern France.* The ropes should be shorter than the depth of water to keep them off the bottom and thus out of the reach of predators. They are usually suspended from one sort of float or another, made either of wood, of fiberglass-covered plywood pontoons, or more modernly and economically, of Styrofoam. The rafts can be as large as seventy-five feet square, supporting up to 700 ropes, or smaller for modest ventures. Some thought should be given to handling the ropes after the mussels are grown, for a thirty-foot rope loaded with adult mussels is not a thing to be lifted by hand. A winch, whether hand- or power-driven, and a boom sufficiently high to lift out at least part of the ropes while the mussels are removed, would seem essential.

Through each rope at foot-and-a-half or longer intervals are inserted wooden sticks (half-inch dowels will do) to keep the

*See *Blue Gold*, by C. Graham Hurlburt and Sarah W. Hurlburt, privately printed in Duxbury, Massachusetts, November 1974.

mussels from sliding off. The new synthetic ropes, half-inch or more in diameter, are probably the most practical, locally-available ropes. During the spawning season young mussels may attach themselves to the ropes suspended for this purpose. Or juvenile stock may be gathered from a natural spawning area and placed in water-soluble rayon or cotton netting, which will disintegrate in a short time, leaving the young mussels clinging to the rope by their byssus threads.

With normal growth, mussels will have to be thinned and transplanted several times a year, or their fast growth and bulk will cause them to fall off. Each time they are transplanted the process is repeated, the young mussels being placed in netting and the netting being wound spirally around new ropes. A thirty-foot rope might produce as much as 250 pounds of mussels in a year. This type of culture, commonly used in Spain, produces something over 200,000 tons of mussels annually there.

RAFTING IN TRAYS

To grow mussels off-bottom in relatively shallow water, the same technique used in "cold-framing" laboratory-hatched quahogs has worked very well. The floats are the same as those used in quahog culture, but the trays are shallower and not filled with soil. Furthermore, the floats will support three trays suspended crossways, each tray starting off with five bushels of seed, growing during the summer months to nearly ten bushels of salable mussels.

The materials needed to build the trays are the same, except 2 x 4's on edge are substituted for 2 x 8's. The thirty-six square feet of plastic window screening may be left out if the mussels are large enough not to fall through the one-inch supporting screen, or if they are in big enough clumps. There seems to be no need for the 2 x 2-inch covering, in fact, if it is used the mussels may climb up and cling to it.

Since young mussels are very sensitive to light, the trays should be dropped down somewhat from the floats, two feet or so, or the mussels will crawl out from under the floats to the ends of the trays. Furthermore, if the trays touch the floats, the young mussels are very apt to work their way onto the floats themselves. This raft and tray method seems by far the most profitable in these waters. There is, practically speaking, no predation since all the enemies are bottom feeders; there is no trash or mud excepting the pseudo feces, or natural wastes, which are easily removed by washing; the byssi are far weaker; and the mussels are thereby more easily and less destructively "de-clumped."

A third method of off-bottom culture is extensively used in France, the so-called "Bouchot" method. I know of no one locally using this method, perhaps because of the damage which could be caused by moving ice. In France, oak poles about eight inches in diameter are driven or pumped into the bottom about three feet apart, in rows twelve feet apart. In the south of France, ropes are simply laid out in the spring spawning season to catch young mussels and then wound spirally about the poles, whereas in northern France, with a far greater tide fall and correspondingly faster current, the ropes are brought in from the south of France and wound on the poles. In some cases a piece of sheet metal is secured around the bottom of the poles to prohibit, or at least discourage, predators from climbing. As in other types of mussel culture, the growing mussels must be thinned from time to time. Also, any new juveniles which may occur must be moved to other locations, in this case in netting bags wound spirally around the poles.

Seed mussels may set in trays with or near the adults, just as they do in both pole and suspended-rope culture. Usually, it has happened with us that they will be off to one side, perhaps tangled with floating eelgrass in the fall; sometimes hanging over the edge of the tray, the clusters held together only by the eelgrass and their own byssus threads. These should be removed to another tray for the next year. It should be noted here that while seed mussels may occur where there is any type of mussel culture, in the Netherlands, in France, in Spain, and on Cape Cod, most of the seed is gathered in natural spawning areas and transplanted to artificially created growing grounds.

HARVESTING

When harvesting adult mussels, the clumps should be broken up as little as possible, since breaking them up pulls the byssus threads from inside the mussels. This is so particularly in bottom culture where the threads are apt to be very strong. Once harvested, the adults should be placed in burlap or net bags (the Dutch use jute) and allowed to soak underwater for twenty-four to forty-eight hours to give the broken threads a chance to heal. The lack of this soaking, this healing process, is one of the major reasons mussels have acquired the reputation for spoiling "in the show case." The broken byssus threads must be given a chance to heal if the mussels are going to be held out of water for any length of time. Again in bottom culture, the mussels should be thoroughly washed and as much trash as possible removed to bring a higher price.

PRECAUTIONS

Three warnings about mussels: If you harvest "wild" mussels, either to be sold separately or to be mixed with your cultivated crop, take only those below mean low water, for two reasons. They will be fatter since they have been able to feed continuously, and in addition, any shellfish exposed too long to the hot sun should be suspect, as some mussel beds are exposed for the greater part of the tide. (This is not necessarily a consideration if the harvested "wild" mussels are to be held in trays for a future crop.)

Second, mussels do not take kindly to long periods when water temperatures are in the eighties. Their growth is slowed, and exposure for too long to these temperatures can cause considerable mortality, whether from excessive heat or from a lack of proper food. There is not much you can do about it except to pray for rain. After they have started growing again, the mussels should be culled over and the dead shells removed before any attempt is made to sell them.

And last, but still important, is mussels' extreme susceptibility to pollution, particularly to so-called "red-tide," *Gonyaulax tamarensis*. It would be wise, if there has been any history of this dinoflagellate's having had an outbreak in your community (and it will cost you nothing in Massachusetts except the trouble of taking your stock to the laboratory), to have your Department of Environmental Health check for you to be sure your mussels are clear. Even if the count is high, you may not be delayed for too long, since, while mussels seem to be the first to ingest *Gonyaulax*, they are also the first to clear themselves of it because of their very rapid filter feeding. *Gonyaulax tamarensis* will not hurt the mussels.

Mussels, then, may make a very good "second crop" for anyone specializing in quahog or clam culture, since usually mussel seed is available at little or no cost other than the gathering and may be gathered at almost any time except the dead of winter, and since trayed mussels take little care other than the occasional separation of the juveniles from the adults. Just be certain that mussels are not planted on the bottom too close to your clam beds, as they might spread and smother the clams.

5 OYSTERS

A TYPICAL HISTORY OF THE CONFLICT BETWEEN PUBLIC LAND AND PRIVATE GRANTS

In order to illustrate the problems that may face the average shellfisherman, I will describe a typical case of the conflict between public land and private grants.

A short history of the oyster industry in Eastham, Massachusetts: Oysters were found in great abundance on the flats at the time of the first settlement in 1620, "but by 1769 the inhabitants had so increased and the oysters were taken in such great quantities for home consumption and for the Boston, Salem and Portland markets that it became necessary to prevent their entire destruction, for the district to take measures to preserve and propagate them. Permits were issued, the amounts and months of taking were controlled. In spite of these controls," the Reverend Pratt says, "in 1770 all the oysters in the Bay died."*

* *A Comprehensive History of Eastham, Wellfleet and Orleans, from 1644 to 1844,* by Rev. Enoch Pratt, published by W. S. Fisher & Co., Yarmouth, Massachusetts, 1844.

Later authorities place the time of disappearance of the oysters in this area in 1775 and lay the blame on over-fishing, particularly of the large breeding stock, and on the taking of shells needed to catch oyster seed, or spat, to be made into lime for fertilizer for their fields and plaster for their homes.

In 1775 Eastham chose a committee to join with Wellfleet to propagate the growth of oysters in the bay. Inhabitants of the towns tried the experiment of bringing in adult oysters and laying them down on the flats, which succeeded well. Within a year they doubled in size and their quality was much improved. This became big business, and by 1844 the number of bushels which were brought in annually for "fattening" was about 60,000.

(Here the oyster business of Wellfleet and Eastham becomes so entangled it is impossible to unconfuse it. Much of the ground used was in Eastham, but most of the men came from Wellfleet.)

In 1876 the first attempts to raise oysters from seed is said to have been made by E. P. Cook. He went to Somerset, Massachusetts, bought 500 bushels, and planted them in Eastham waters. "The people laughed at him for dumping his good money overboard." The oysters all lived and by next spring showed a remarkable growth, such that they caused a stampede among those who had laughed. By 1892 some 200 acres in Wellfleet and 800 in Eastham were under cultivation at a fee of $3.00 an acre for the original grant and $1.00 a year rent thereafter. By 1907 that acreage had more than doubled.

Previous to 1840 the oyster industry, just as the clam, scallop and quahog industries today, was considered common property. But with the obvious decline of the supply and the bringing in of southern oysters for fattening and resale, the oyster industry took on a different look. By 1890 oysters had become a crop dependent on private capital, even though planted on leased public land, whereas the harvesting of other shellfish required chiefly labor with little capital other than for equipment.

The regulations regarding grants, as these leased areas are called, were extremely shortsighted until recently in Massachusetts, and continue to be so in many states. The laws were short-term and preventative rather than constructive, so that by 1910 no one was willing to gamble on a crop which might be taken away from him in ten years. Since quahogs and scallops grew on ground set aside for oyster culture, many and bitter were the arguments between quahogers and oystermen. In the end, the quahogers, being in the majority, all but forced oysters off the market.*

There are two reasons for including the above description: first, it shows that aquaculture can be successful, and second, it is a warning against the eventual, inevitable course of a shellfish program (or non-program) dependent entirely on nature as a source of future crops.

RANGE

One kind of oyster or another grows practically all over the world.** On this coast oysters grow from the Canadian Maritimes to Florida and into the Gulf of Mexico. Wherever they grow, they need a firm, preferably sandy, rocky or shelly

* From the *Eastham Vacationist's Handbook, 1971-72*, by Phil Schwind.

** This chapter deals with the cultivation of the American oyster (*C. virginica*), the only oyster allowed in Massachusetts at this time, since all other oysters are considered "exotics" by the controlling authority, the Massachusetts Division of Marine Fisheries. A great deal of work is being completed successfully in Maine with the European oyster (*O. edulis*). It stands colder temperatures, which gives it a longer growing season; it stands higher salinities, which gives it a wider growth range; and it seems to grow faster, which shortens the time from planting to harvesting. The one drawback seems to be that its "shelf life," that is, the time it can be held safely in the market place, is considerably shorter than the shelf life of the American oyster. These are all factors which should be of concern to the aquaculturist. For further information on European oysters, see *Experiments and Observations on Swarming, Pelagic Life and Setting in the European Flat Oyster (Ostrea Edulis L.)*, by Pieter Korringa, Elsevier Scientific Publishing Company, New York, 1940, o.p.

Left: "Banana" oyster. The elongated shape due to crowding.
Right: "Box" oyster. The desired shape for the "half-shell" trade.

bottom. They may grow on spiles and rocks, but they cannot grow in silt or soft mud, which smothers them. Hard mud/clay can be firmed and built up by depositing sand, shells or coarse gravel, or a combination. Indeed, in some places it is common practice to dump loads of clean scallop shells on the bottom to insure a catch of oyster "spat" (so-called because it was once thought that oysters spat out their seed).

GROWTH

Oysters will set and grow from between the tide lines off into deep water, from water with a high saline content to almost brackish water (though fresher water will cause thinner shells). Once established, oysters can stand a stronger current than most shellfish; in fact, a stronger current may be desirable to carry away silt. In parts of the Netherlands: "One special feature is that after being planted out the oysters mostly end lying on their flat side, because the force of the first high tide rolls them over from their convex side. This gives them a 'streamlined' appearance on the oyster banks southeast of Yerseke, and is one of the reasons for the whiteness of the shells of Dutch oysters."*

Most of the factors which govern the growth of other shellfish apply to oysters. They must have an adequate current to bring food, oxygen and lime, and to carry away waste and silt. Temperatures of from forty to eighty degrees F. are the most productive, and the shorter the oysters' exposure to air the more rapidly they will grow. Below forty degrees American oysters seem to go into a sort of hibernation, and, although they will lose little or no weight, they will cease to feed, or even to open. Obviously, the colder the average temperature of the water, the shorter the growing season.

Oysters will probably not grow more than an inch in length the year they are spawned, and, depending on the location and conditions, will take from two to five more years to reach a marketable size (three inches). Spawning occurs during the oyster's second year, but full spawning potential is not reached for at least another two years. If the oyster is ready (and *only* if it is ready) spawning occurs when the water reaches sixty-eight to seventy degrees.

Once the spawning occurs the seed swims and drifts about, unprotected and without a shell, for approximately a week or more, depending on the climatic conditions. At the end of this time it sinks to the bottom and clings to the first hard, *clean* object with which it comes in contact. There it attaches itself and secretes a sticky material which hardens to become the oyster's permanent mooring. It cannot adhere to a slimy or

* From *Agricultural Newsletter from the Netherlands*, No. 1, 1976.

plankton-covered surface. It is for this reason that cultch (seed-collecting) material should not be put out prematurely.

While there have been great improvements in hatchery techniques in the last few years, no one is quite sure what causes the ups and downs of natural production on established beds. There are several questions yet to be answered: Is there some sort of cultivation of the bottom which would result in higher spatfalls? The deposition of clean sand, gravel and/or shells certainly helps. Is there something important in the density with which oysters are farmed so that simultaneous spawning may be stimulated? The answer seems to be "yes" as with other shellfish. Why do some areas have a heavy annual set, while other areas of proven reliability in growing oysters must use imported seed?

We do know that a cold rain will either kill or drive to the bottom all free-swimming oyster larvae, that the best years in the areas where oysters set naturally in abundance are those years with little or no rain during July and August (e.g. Wellfleet, Massachusetts, in 1975). A natural set is most likely to occur between the tide lines, though the oysters are safer if moved to deeper water because of winter conditions, freezing weather and ice movement, and because temperatures are too high on the flats during the summers.

METHODS OF OBTAINING SEED

Of the methods of planting oysters, the harvesting and transplanting "wild" native seed is the cheapest and simplest, since little besides labor is involved. Unfortunately, there are relatively few areas where an abundance of this sort of oyster seed is available, and in many of these areas local ordinances regulate or completely prohibit the removal of such seed.

If your grant happens to be adjacent to such an area and you are forbidden to move seed, your best alternative is to set out seed-catching devices. You may set out, at the proper time, cultch bags on your own grant, with an eye to more evenly distributing the seed when you have caught it. The cultch bags, made of the cheapest possible one-inch chicken wire, will hold your cultch shells long enough before rusting out for you to catch seed and replant it. Those we used were made of four-foot lengths, two feet wide, of one-inch wire, folded in the middle and "sewed" around two of the remaining three open sides with cheap, black iron wire. Then the bags were filled with clean scallop shells, and the last side sewed up.

While oyster shells, rather than any other shell, are most frequently recommended for the collection of seed oysters, we preferred scallop shells, since they are more fragile and thus easier to break up, separating the "clusters" of oysters so they may grow to uniform shape. (There is much to be said for blue mussel shells if they are available, because they practically disintegrate by themselves after a year or two.) Too heavily clustered oysters, because of the lateral pressure, tend to form elongated "banana" oysters, which, while they are suited well enough to the opened oyster trade, are almost unsalable in the half-shell trade, which demands a uniform "box" oyster.

PREPARATION OF SITE OR TRAYS

In off-bottom culture, cultch strings are the best means of catching oyster spat. The common practice is to perforate clean scallop shells and string them back to back with rubber or plastic "spacers" between the pairs of shells on a length of "self-destructing" iron wire. However, we found that at times the wire rusted out before we were ready to transplant the clusters of oysters caught on the shells, and we lost a considerable quantity by their sliding off the broken wires. Apparently some of the hatcheries had the same experience for more recently the strings have been coming through on heavy nylon cord. The original spacers were three or four inches long, but we found that by reducing their length to an inch or so, or by eliminating the spacers altogether we could get more shells on a string and thus catch more spat per string.

The proper length of cultch strings is somewhat debatable.

Cultch strings to catch American oyster seed. These are scallop shells, perforated and strung on heavy nylon cord, and separated by spacers made of old garden hose. The cultch strings are set out near spawning oysters during the spawning season to catch oyster spat or seed.

We found strings five or six feet long easy to handle and productive (when the oysters had reached marketable size) of about a bushel of oysters per string. While we ourselves found no difference in the growth of the oysters at the top or at the bottom of the strings, in some areas, if the oysters are suspended too deep they will grow in pyramidal form, that is, oysters at the top will be much larger than those at the bottom of the string. Presumably this is due to the opacity of the water, although we have no scientific proof of this reason. The theory is that the darker the water (that is, the more suspended silt), the less sunlight can penetrate, thus the less phytoplankton which needs sunlight, thus less food, thus slower growth of oysters.

The important element to remember in setting out any spat collector is that it must not be set out too soon, because, as mentioned before, exposure for too long to natural conditions will almost surely result in collecting slime and planktonic growths which will prohibit the attachment of oyster spat.

The alternative to catching your own spat is to buy hatchery seed, in most cases relatively inexpensive as compared to the price of marketable, adult stock. Whether it is to be spread on the bottom or placed in trays, or, as in the case of seed, caught on cultch strings, the one thing to remember is that it must be handled quickly. Also, it must be kept out of the rain and especially out of the hot sun.

If you are engaged in bottom culture, be sure the bottom is ready before your seed arrives. If you are going to sand it or spread shells over it, do so early enough to give the bottom a chance to settle. Remove all possible predators, and then you are ready. If off-bottom culture is to be your method, have the floats ready, whether for trays or cultch strings.

As far as growing oysters to maturity on cultch strings is concerned, we found that with a heavy set on the scallop shells, eventually the oysters got too big and broke the shells, thus dropping the growing oysters to the bottom where (in our case) because of the sticky, soft mud below they were smothered and lost. Furthermore, if there was much movement of ice during the winter, some of the strings were literally torn off the supporting floats. For that reason we hung the cultch strings until just before cold weather. (Since the seed had been caught the previous summer, that would make the stock thus raised a year and a half old.) Then we put the oysters, either strings and all in the trays, or we broke up the strings and spread out the oysters in trays similar to those used in mussel culture. The latter method gave much more uniform oysters, though in case of accident, such as trays breaking adrift or being crushed by the ice, the loss in oysters was less if we left the strings intact during their second winter, breaking them up and spreading out the oysters in the spring.

The trays may be supported crossways to the floats, as in mussel culture, with up to five bushels in each of the 3- x 12-foot trays (four inches deep). Do not suspend the trays one under the other, that is, stacked and secured to each other, without adequate room for water circulation. If there is not sufficient tide flow, only the oysters on top and on the bottom will grow, the oysters in the middle usually living but not increasing in size.

Depending on the rate of growth, which will vary from place to place and from year to year, the clusters of oysters should be broken up, if not during their second year, then certainly at the start of their third year, and spread out evenly to grow without crowding.

HARVESTING

When the crop has grown big enough and the market is right (remember, after the oysters spawn, from July through September, they will be thin, watery and sometimes bitter) they should be harvested. Here the off-bottom culturist has the easier job. The trays may be towed ashore, close in on the high tide, and picked over at low. Next easiest to harvest are those oysters grown in water no deeper than wading depth, where they may be picked up by hand with scratcher or rake. In deeper water oyster tongs, or in some cases bull rakes, are frequently used. Deeper grants, of course, may call for power dredging.

PREDATORS

As far as enemies go, they vary depending on location. In some areas starfish can be deadly, wiping out entire crops, while in other areas oyster drills almost prohibit bottom culture, particularly where very young oysters are involved. Moonsnails are more likely to attack clams and mussels, but if not thinned out can also be very destructive to oysters. Japanese codium (green, marine algae) has lately become a threat to oyster growers in some areas, attaching to and growing on exposed shells, and eventually floating the oysters off the grant. Eelgrass is harmful only if it grows so thick as to cut off current. These predators are harmful only to oysters grown on the bottom. Add to them flat worms, which seem to do adult oysters little harm, unless they are very thick, and the boring sponge, which is harmful to the shells of older oysters. In some cases blue mussels can be a nuisance, most particularly if they set on cultch strings.

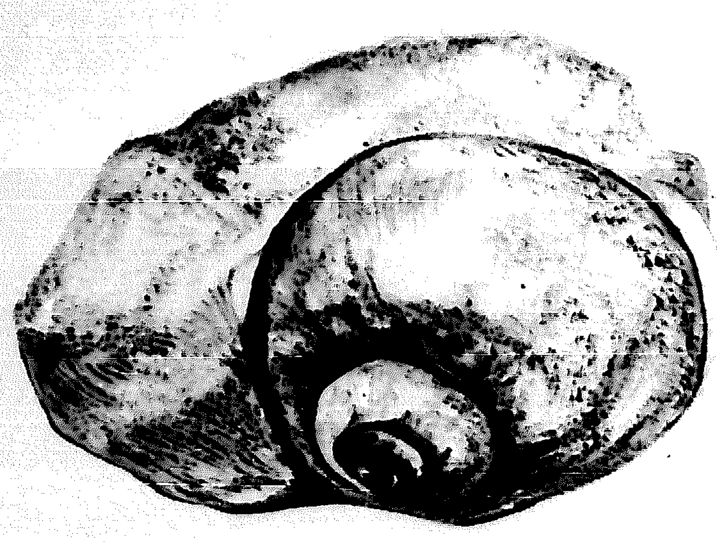
For the small operator, clean and attractively packaged oysters will bring a bigger margin of profit than those handled the easier way of shipping them onto the open market in bulk. As long as the packaging costs are kept at a reasonable range, this method can be expanded profitably to take the yield of a fairly large operation.

6 PREDATORS AND THEIR CONTROL

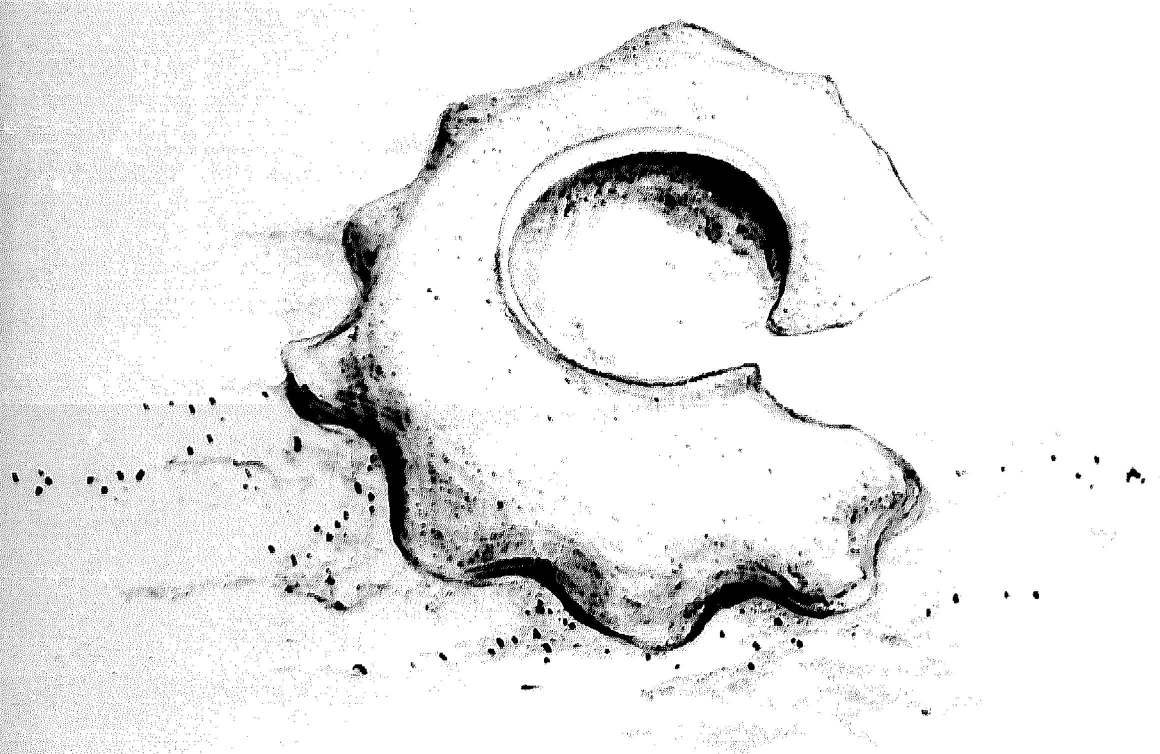
This list of shellfish predators may seem fairly long. Presently, there is no practical chemical means of reducing it. This latter fact may be a blessing rather than a disadvantage, since without chemical additives, at least the marine farmer is not polluting his own environment. With the exception of one or two predators, however, none of them is a problem to off-bottom culture of any kind of shellfish. In addition, most of them are localized, and so may be controlled, if not eliminated, by hand methods in shallow water. Furthermore, not all of them occur in the same places, and not all of them are especially harmful to every kind of shellfish.

MOONSNAILS

The moonsnail, also called "moon shell," "cockle," "round winkle," and "round wrinkle," attacks most shellfish but it is particularly an enemy of the soft-shell clam and the quahog. It is technically divided into two categories, the northern moon-



Southern moonsnail. Feeds on adult quahogs, blue mussels, oysters and soft-shell clams. May burrow as deep as six inches.



"Sand collar." The egg case of the southern moonsnail. It is composed of sand, eggs and a mucous nutrient. Each egg case may contain as many as 3,000 eggs, and the female may lay more than one such collar a year.

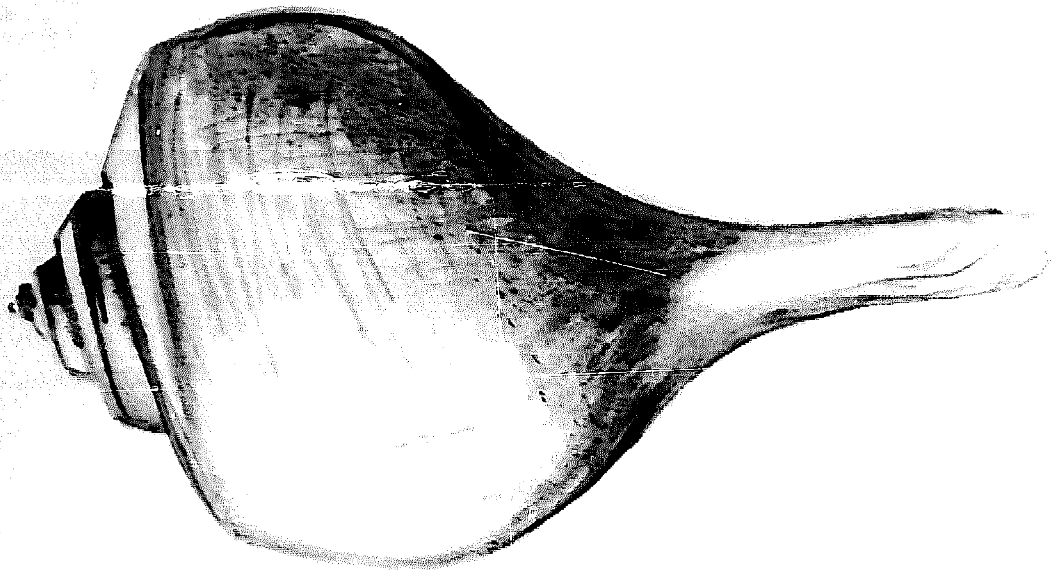
snail and the southern moonsnail. The range of the northern is usually considered to be from Cape Cod and the open waters thereabouts north.

It is said to get to be as much as four inches in height and is ashy brown in color. The shell is thick, globular, and has a very thin, yellowish-brown periostracum (the layer surrounding the shell). There are about five very convex whorls, somewhat flattened at the top. The aperture is large and oval, and the operculum (shell cover of the aperture) is horny. It, like the southern moonsnail, buries itself in moist sand, its whereabouts being indicated by a short, wide trail and a small mound.

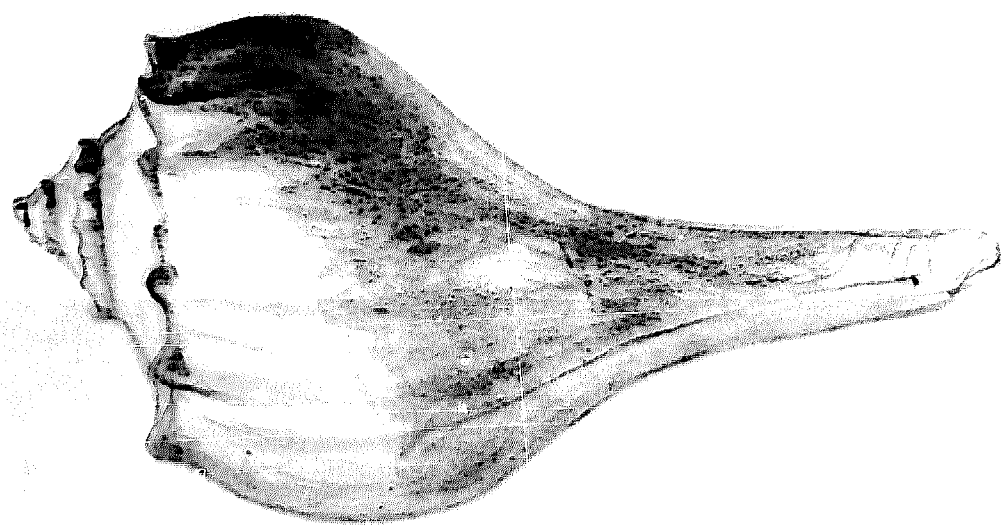
On the other hand, the southern or lobed moonsnail is somewhat smaller than its northern cousin, and even more destructive. Its range is from Cape Cod south. It is doubtful that the commercial fisherman bothers to differentiate between the two where their habitats overlap. It sometimes grows to about two inches in height by nearly three inches in diameter. Its shell, sometimes chestnut brown but usually tinged with blue, is solid and oval, the upper parts of the whorls compressed, to give it a somewhat conical appearance. There are four or five whorls. The aperture is oval and oblique, the operculum is horny. It may be recognized instantly by its brown lobe of shelly material.

Both moonsnails spawn in the late spring or early summer. Their egg cases, so-called "sand-collars," are commonplace along sandy, protected beaches and should be destroyed wherever found. They are composed of sand, a mucous nutrient, and as many as 2,500 to 3,000 eggs. More than one egg case may be laid by one female. In two weeks the eggs hatch to free-swimming larvae, which set in thirty-five to forty-five days.

They are active in the warmer months, feeding on soft-shell clams, quahogs, blue mussels, and if nothing else is available, on gem clams, mudsnails and each other. The southern moonsnail is usually the more destructive, and has been known to eat as many as five two-inch clams in a week. It prefers a more brackish water to a highly saline one, while the northern variety prefers the saltier water at the mouths of bays and harbors.



Channeled whelk, an enemy chiefly of oysters and adult quahogs. These may be trapped or potted, and varying markets exist for their use as food or bait.



Knobbed whelk, like the channeled whelk, chiefly an enemy of oysters and quahogs. They are difficult to trap or pot since they cannot or will not climb the steeply slanted or wire-covered sides of a pot. Best controlled by picking them up by hand and by destroying their strings of disk-like egg capsules.

The northern may dig down a full two inches, while the southern variety has been known to dig six inches or deeper.

Moonsnails can be picked up by hand in shallow water or on the flats, most successfully on muggy, foggy mornings. In deeper water slat-sided traps, eight to ten inches in height, baited with chopped-up horseshoe crabs or fish gurry may prove successful. *A sustained, determined effort can clear a given area of practically all the moonsnails there.*

It is said that moonsnail meat is edible when tenderized and properly prepared. It is more commonly used, either ground or whole, as fish bait.

WHELKS

The whelks, both knobbed and channeled, commonly called "conks," can be very destructive in some areas, though in proportion to their size, they are not as hungry as moonsnails. Some communities require a special license for conk-potting.

The knobbed whelk may get to be very large, five to nine inches long, and as much as five inches wide. The shells are pear shaped, heavy, with an ashy to sand color, sometimes with brownish axial streaks when young. There is no periostracum. The operculum is large, rough, and grayish-brown. The sutures are shallow and the outer edge of the body whorls bears a rim of low knobs. The shell is much harder than that of the channeled whelk. The color of the aperture is bright brick red to gleaming yellow.

The channeled whelk is also large, as much as eight inches long and five inches wide. The shell is thin, covered with a hairy, brown periostracum. The outer rim is thin, the body whorls strongly shouldered with the sutures somewhat deeper than those of the knobbed whelk. The operculum is like that of the knobbed whelk.

The range of both of these shellfish is from Cape Cod south. The spawning period is in late spring or early summer. The eggs are laid in long strings of joined capsules, as many as sixty or seventy in a string, and each string may contain as many as 60,000 eggs.

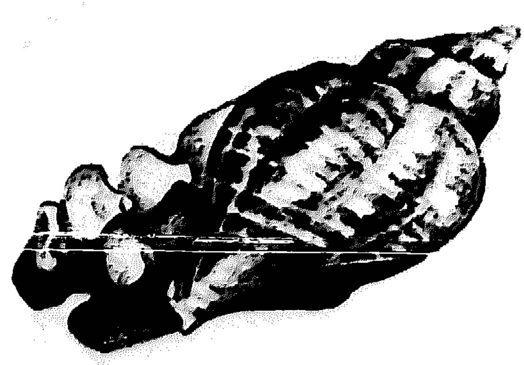
The eggs emerge from the capsules as fully formed, miniature snails, with no free-swimming period. Whelks are particularly destructive to quahogs and oysters. They chip away at the edges of their victim's shells and force them apart. After they have finished feeding, they will bury themselves in the sand until they again crave food. They migrate diurnally as well as seasonally.

Channeled whelks may be potted successfully with the same sort of wooden, slat-sided trap used for moonsnails (be sure the opening at the top is wide enough for their entrance) while the knobbed whelk, although occasionally trapped in pots with a lower profile, is most successfully picked up by hand at low tide.

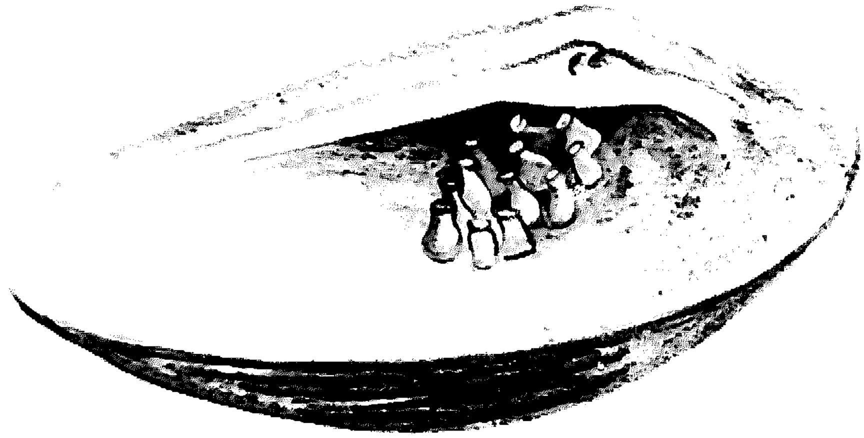
Whelks can be tenderized and pounded into "tasty steaks," but are more commonly used as codfish bait.

OYSTER DRILLS

The Oyster Drill grows as large as 1¼ inches long by 5/8 inch wide. The shell is shaped like an old-fashioned spinning spindle, with nine to twelve rounded axial ribs which are more widely spaced at the outer whorls. These ribs are crossed by shallow, narrow, spiral ridges. Their color is usually ashy-gray. The operculum is horny and amber-colored.



Oyster drill (more than two times normal size) extruding egg cases.



Oyster drill egg cases hidden in an old quahog shell.

Their range is from Canada to Florida and their life expectancy is probably ten years, though they are sexually mature in one year. Their spawning period is usually in early summer to late fall, although they have been known to spawn in the winter. The eggs are laid in small capsules, usually yellow and finger-shaped, which are attached in clusters to solid objects, such as rocks, old quahog shells, and so on. Each female can lay up to fifty capsules with as many as ten eggs per capsule. The eggs hatch in twenty to fifty days, depending on the water temperature. The young then cling to the sides of the egg cases before crawling away.

Oyster drills prefer mussels or barnacles to oysters, and are more dangerous to young, thin-shelled oysters than to older ones. The drill penetrates its prey by alternately rasping at the shell and secreting shell-softening enzymes. When a very small hole is drilled through the shell, the drill inserts its snout into the hole and devours the meat. While it can crawl from fifteen to twenty-five feet per day, it is more readily distributed by attaching itself to moving invertebrates. It is particularly destructive to mussels, oysters and scallops, but will eat young clams and other shellfish found near or on the surface.

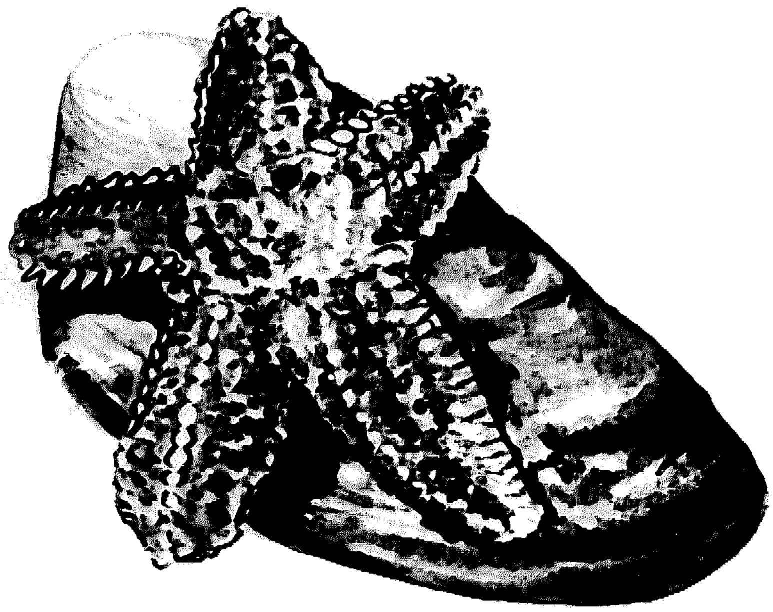
If there are oyster drills in the vicinity of your grant, the advice most commonly given is to move your oysters some place else. The alternative is to go into off-bottom culture, at least while the oysters are young and thin-shelled. Since these alternatives are not always possible, oyster drill "traps" may be made by putting cement blocks or tiles where barnacles are prevalent. When a good set of barnacles has attached itself, since the drills prefer barnacles to oysters, the blocks may be scattered about the grant and tended daily to remove the drills (always including the egg cases, of course). Clumps or net bags of blue mussels may be used in the same way.

Polistream-sevin, a chemical pesticide once thought to be a cure for drills, apparently does them little harm and is definitely deadly to other invertebrates. *Do not use.*

STARFISH

The common starfish usually has five arms, is reddish-brown, and grows up to ten inches in diameter. It spawns during the summer, liberating thousands of eggs into the water, where they are fertilized. Its free-swimming larvae drift with the tide for weeks, then settle, attach themselves to an object, and grow arms before freeing themselves.

The starfish's feeding habits are unpredictable except that it is a voracious feeder, attacking even shallowly buried shellfish. Wrapping its arms around a bivalve, it exerts pressure with the multitude of vacuum cups on the inside of its arms to force open the shells. As little as an eighth of an inch will do for it to insert its stomach and, with the aid of digestive juices, it will digest the meat of its victim. Starfish can be particularly deadly to small, exposed shellfish. While it crawls relatively slowly, it has been observed to take advantage of a tidal current by curling up the tips of its arms and drifting along just above the bottom, traveling thus a considerable distance. It has no particular value, and even sea gulls scorn it as food unless they are very hungry. It is particularly harmful to oysters, mussels, juvenile clams, and bay scallops.



Starfish attacking blue mussel. Starfish are particularly deadly for surface-growing shellfish, oysters and blue mussels. Small starfish will attack juvenile clams and quahogs.

In shallow water, the most efficient way to remove starfish is to pick them up by hand, particularly if they are small. To save bending over, a sort of harpoon may be made by straightening out a heavy fish hook and securing it to the end of a broomstick. Just remember that starfish have strong rejuvenating powers – tearing one in half will probably result in a three- or four-legged starfish, fully as destructive as its former five-legged self.

In deeper than wading bottom, a rag mop seems the most effective way of removing starfish. The rag mop is made of a heavy iron frame, two feet or wider, depending on your towing equipment (and also to some extent on the evenness of the bottom). A scallop drag frame without the attached net bag will do nicely. Connect the two legs with an iron rod or heavy wire. From this crosspiece, at six or eight inch intervals, suspend wires or pieces of light chain two or three feet long, to which have been tied overlapping clusters of any twisty, fibrous material, cotton waste or unstranded rope. The more snarly the clusters of rope the better, since, as the rope is towed along the bottom slowly, the spiny surfaces of the starfish become entangled. If the infestation of starfish is heavy, the mop should be brought aboard frequently and the starfish picked or shaken off. To speed this removal of starfish they can be dunked in a trough of hot water (supplied perhaps from the water-cooled engine exhaust) or more practically into a trough filled with salt-saturated brine. A two-minute soaking in brine is long enough to soften and kill all the starfish; a longer soaking may result in their being pickled, and stiffen them so they will have to be removed by hand. This is the most commonly used equipment locally.

Broadcasting quicklime over a shellfish grant is one method of killing starfish, as it needs only one particle of quicklime to touch a starfish to kill it within a day or two. However, broadcasting a dry substance on the surface of the water at any depth is a tricky business, since the slightest tide may carry it completely away from the area you want to cover. It seems as though the rag mop is the surer method.

BLUE CRABS

The blue crab is really green, shading to pale blue on its legs. The after pair of legs is flattened to aid in swimming. It ranges from Nova Scotia to Mexico, being somewhat more plentiful in the warmer climates. Its life expectancy is three years, and it matures during the second year. The male spawns only once, but the female receives enough spermatozoa to fertilize her eggs for a lifetime. When the eggs hatch, the larvae start through three or four stages, the first stage swimming near the surface of the water. During later stages they swim or crawl nearer the bottom.

The blue crab's feeding habits are diverse, for they feed on both dead and live material. Since the crab not uncommonly grows to as much as nine inches in width, it is capable of break-

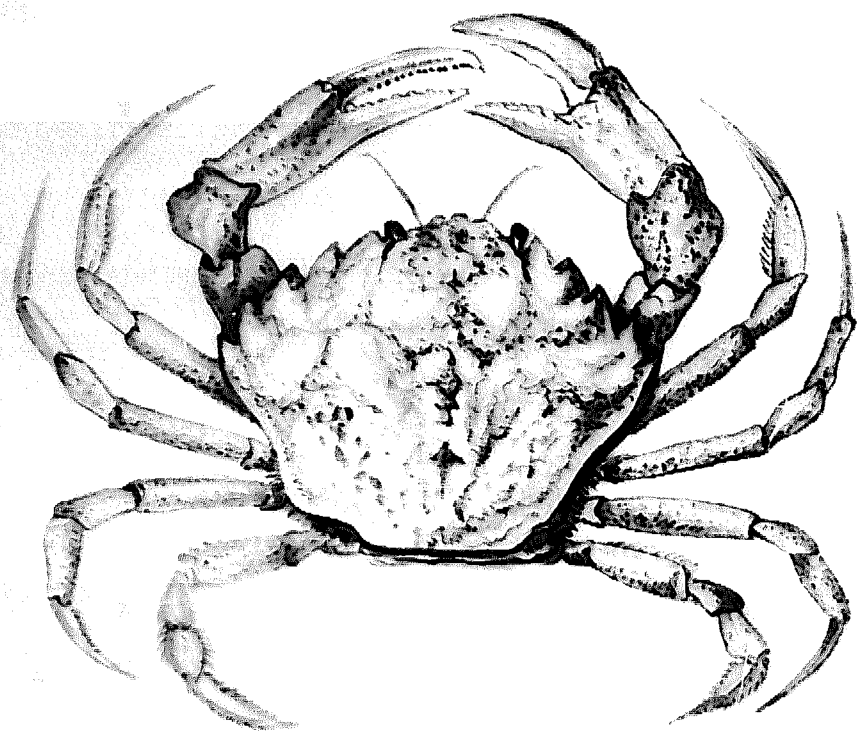
The edible blue crab (or "blue claw" crab) has been known to destroy uncovered, adult quahogs up to 3½ inches in diameter by cracking or chipping away the edges of the shells.

ing open ¾-inch quahogs and is known to break off the edges of fully grown, chowder quahog shells. It is also cannibalistic, feeding on injured or soft-shell members of its own kind. It is particularly destructive of quahogs, especially juveniles in soft bottom.

While blue crabs are considered predators by the shellfish aquaculturist, they are listed as edible crabs, so before you wage war on them, check your local ordinances and the local crab market. At night, in shallow water, they can be caught with a dipnet and a flashlight. In deep water they can be potted, trapped, or trawled, using equipment made especially for the business.

GREEN CRABS

The green crab is smaller than the blue crab and its rear legs are somewhat modified for swimming. Its range is from coastal Massachusetts north into Canada.



Green crab (about 1½ times usual size). They are absolutely omnivorous, eating everything from marsh grass to carrion to living shellfish. They may crack and eat quahogs up to one inch in diameter, and have been known to wipe out completely beds of immature clams. They may be partly controlled by wire fences with down-turned upper flanges, and by potting or trapping.

Its spawning period occurs after the female sheds her shell in the summer. The eggs are carried under the female and when they hatch the larvae drift through the water. Several changes occur until the larvae fully metamorphose into the more familiar shape and settle to the bottom.

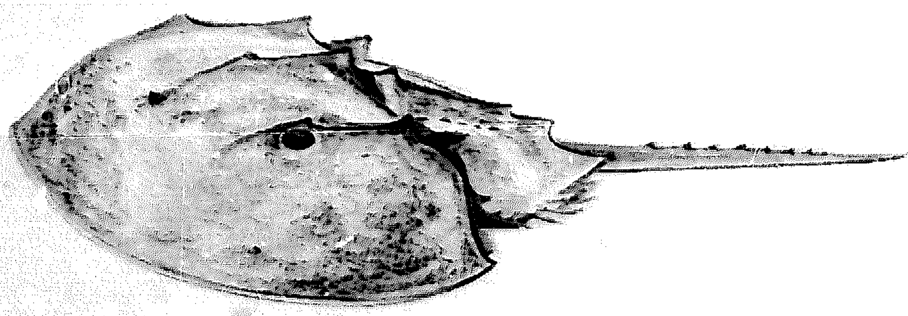
They are almost omnivorous eaters, eating everything from marsh grass to fish. They are particularly destructive to soft-shell clams and small quahogs.

This predator is becoming increasingly destructive. There may be a small market locally for green crabs for bait for tautog fishing; otherwise, they should be destroyed before you lose all your juvenile shellfish. Some of them may be caught in pots designed specifically for green crabs, which may be made of half-inch, vinyl-covered wire, built square or around a hoop, and slanting to a narrow opening at the top. From this opening some sort of baffle must be extended down into the pot to keep the crabs from crawling out.

If the crabs are particularly bad it may pay to build a fence during the summer months all around your grant. This can be made of three- or four-foot wide (depending on the depth of water at high tide), one-inch mesh, galvanized chicken wire, with the bottom edge buried in a trench four to six inches deep. The fence should than be staked securely enough so it will not be washed out by wave erosion, particularly when it has collected drifting weeds or eelgrass. At the top, curving out and down, there must be a flange of some sort, either made of the wire itself or of 1 x 6 boards, nailed down-slanting to the fence stakes. This will keep out most of the larger crabs (as well as horseshoe crabs, moonsnails, and conks) but you may have to pick up by hand those little green crabs that may have made their way through the wire. At low tide, pick up and destroy the larger crabs spending low tide snugly against the outside foot of the wire. Apparently, green crabs feed mostly at night and at high tide, and their heaviest attacks are during the six or seven months when water temperatures are above forty-five degrees. (This means you can remove the fence when there is danger of ice movement, taking it out to save it for use another year.)

HORSESHOE CRABS

Despite Woods Hole Oceanographic Institution research and articles on the farming of horseshoe crabs for their "blue

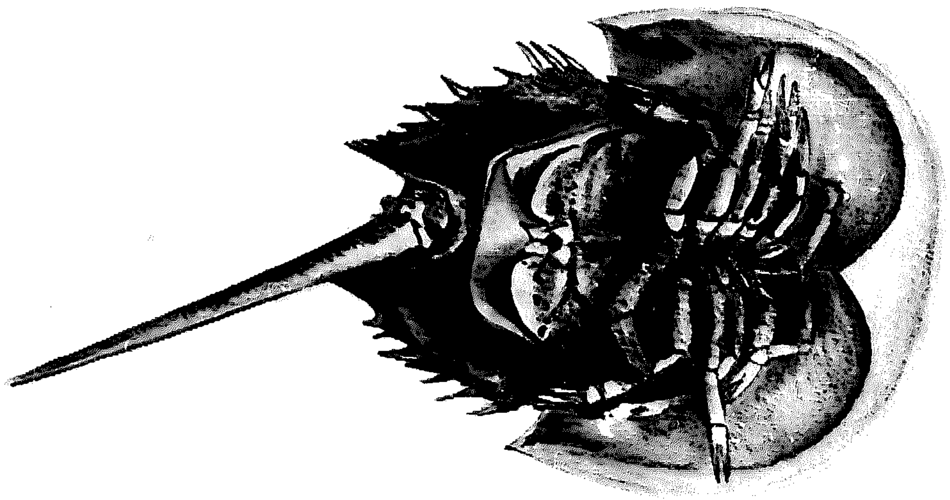


Horseshoe crab, an enemy chiefly of very small quahogs and juvenile clams up to one inch in length. A three-inch wide horseshoe crab has been known to eat as many as 100 small clams in a day.

blood,"* it is a fact that they are extremely destructive. Horseshoe crabs range along the Atlantic coast. Males are smaller than females. Their life expectancy is from fourteen to nineteen years, though they do not mature until they are between nine and twelve years old. Their spawning period is late spring, when one female may lay up to 20,000 eggs high in the intertidal zone. Tailless crabs the size of a matchhead emerge after about three weeks' incubation. The young molt several times a year (which accounts for the myriad small horseshoe crab shells one occasionally sees in the sea wrack). The shells are split along the forward edge and the young crabs crawl out. From then on they will shed only once a year until they are nine years old. After they become sexually mature they cease to molt. While the adults enter shallow bays in the spring and return to deeper water in the fall and winter, the young remain in the bays for several years after hatching. The males' front claws are designed to cling to the rear of the females' shells.

The young (light brown) are particularly destructive to juvenile soft-shell clams. They feed so actively that a three-inch

* Peggy Thompson, "Value is Extracted from a Nuisance," *Smithsonian* magazine, April 1975.



Female horseshoe crab, underside. The males' forward claws would be club-and-thumb shape, the better to cling to the female's after shell.

horseshoe crab may eat fifty half-inch clams a day – not to mention those it destroys in plowing through sand or mud.

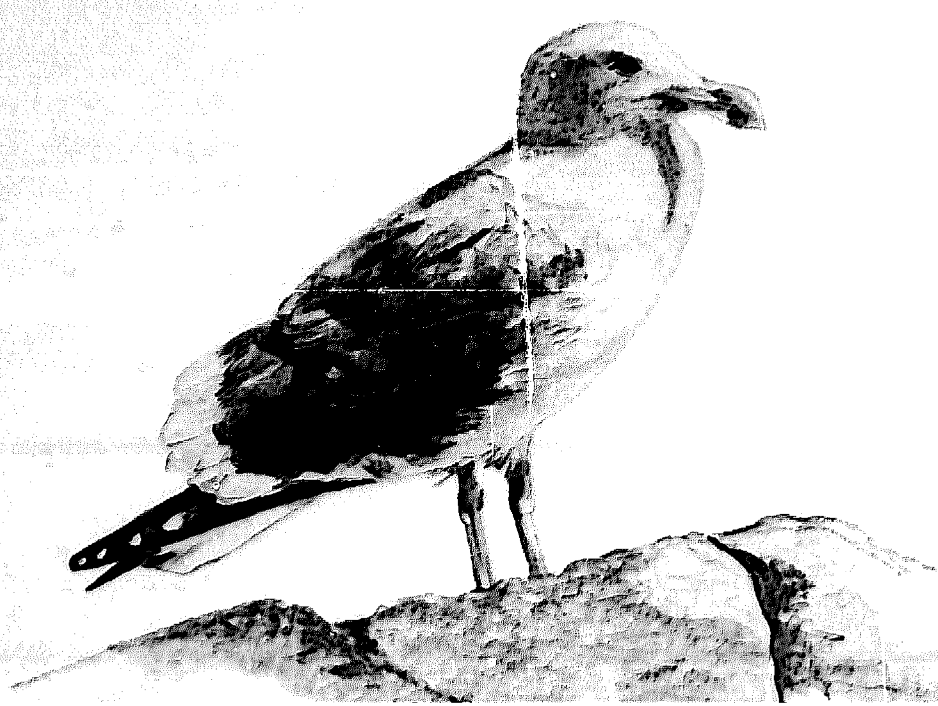
Horseshoe crabs appear in the greatest numbers in shallow water during the spring high-course tides when they approach the beach to lay their eggs. Most of the adults start migrating seaward by the first of July, so the time to render the greatest protection to your grant is in the spring, before the horseshoe crabs have had a chance to lay their eggs. Although various weirs and traps have been tried, picking them up by hand is about the only way to destroy them. They are presently a "money crop" in themselves, being much sought after for bait for eel pots, crab pots, and conk pots. They can be stored for weeks in a half-sunken dory, or in cages or pounds built for the purpose.

SEA BIRDS

Diving ducks, Canada geese and sea gulls can be completely destructive of beds of juvenile shellfish. As regularly as they set each year, beds of young mussels are demolished by diving ducks, eiders and suchlike, which feed at night or in the daytime, at high tide or low. There is no known cure except to shoot them in season. At least one town is known to have fired rockets over a bed of scallops to scare off eiders, with no benefit except the amusement of the local kids.

Canada geese can and do puddle out complete beds of juvenile soft-shell clams during the winter months, bird lovers and the Audubon Society notwithstanding. Working in several inches of water, the geese paddle vigorously to wash out the clams. Their feces left at low tide bear evidence of their diet of clams. Whole annual crops of bay scallop seed have been destroyed by wintering geese. The only salvation, which works only partially on clam seed, is to suspend waving,

Sea gulls, particularly herring gulls, destroy immature shellfish by puddling, and adult shellfish by carrying them ashore to smash them by dropping them on rocks or any hard surface, especially during the winter months.



PRACTICAL SHELLFISH FARMING

"loose-footed" sheets of plastic netting over the entire area. Even then geese will sneak in on the night low tide to puddle directly under the plastic. There is no known foolproof deterrent. Coarse gravel beds for young quahogs will at least slow up goose puddling.

Herring gulls frequently take the blame for the nefarious work of ducks and geese. Not that the gulls are blameless, for they too will puddle out young shellfish, but they are more interested in larger game – adult shellfish ranging from mussels to full-grown quahogs. Since gulls seldom work at night, the line of waving plastic netting is more effective with gulls than with geese. We drove into the mud 2 x 3's, ten feet apart, and from about five feet up we suspended four-foot plastic netting, letting it wave in the wind. It works fairly well with gulls until the ice takes it out. We strung used monofilament fishline a foot or so off the bottom over the clam beds with only moderate success.

WORMS

There are a number of worms which are somewhat parasitical, particularly to oysters. The flat worm sometimes lives in the gills of oysters. Whether or not it is actually harmful to adult oysters is not fully known. It is, however, harmful to oyster spat and juveniles. It is a thin, brown, leaf-like worm growing up to ¾ inch. Its spawning period is during the summer, when eggs are deposited in gelatinous ribbons. After several days the larvae emerge swimming and settle down where oyster larvae do, seeking wherever possible dark places in which to hide. While the flat worm is not harmful to people, its presence does nothing to enhance the value of oysters. Fortunately, it is prone to leave the oysters after daylong exposure to air and light.

Blister worms live on the inside of oyster shells under a film of shell built by the oyster to protect itself. They may be killed by soaking the oyster in brine for a short time.

BORING SPONGE

This animal lives in the shells of oysters or other shellfish, particularly in older shells. It is really not a problem on young shellfish, but as it expands its tunnels in the shell it can destroy as much as fifty percent of the shell itself, thereby making the shell brittle and easily broken. Eventually the boring sponge will pierce the oyster's inner shell. During the summer months the oyster quickly patches these holes with lime and other shell material. The results show up as raised dots like pepper. (This effect may also be seen on very old, "blunt" quahogs.) After the water temperature drops below forty-five degrees the oyster finds itself unable to patch its shell, but the sponge keeps on boring. Eventually it either weakens the shell so that it breaks at the least strain, or it attacks the hinge, killing the oyster.

Just as with blister worms, the boring sponge may be destroyed by soaking the oyster or other shellfish in a saturated solution of brine, for one to five minutes, depending on the length of time the shellfish has been out of water, (the longer out of water, the shorter the required soaking time).

JAPANESE CODIUM

This is a relatively new menace, at least in these waters. A jointed, pulpy, green, marine alga, it is sometimes called "sponge seaweed" because of its soft, spongelike texture. It is also called by fishermen "spaghetti weed." With its many branching stalks springing from a single base, it attaches itself to the exposed shell, chiefly to the oyster, and frequently to scallops. As it grows rapidly it eventually has enough flotation to drift off before wind and tide, dragging the host shell with it. There is presently no known cure except to keep cutting it back, removing as much as possible from the neighborhood.

EELGRASS

Eelgrass may be considered a nuisance rather than a predator. It is harmful chiefly when it becomes so thick as to cut off the flow of water over a grant, or in the fall when windrows of it may smother young shellfish when it has broken off and washed up on a shallow planting. The roots may be smothered in shallow water by putting down sheets of tarpaper and covering them with sand until the roots are dead. Polyethylene may be used in place of tarpaper, and is perhaps more practical since it lasts much longer.

MSX

MSX, now called *Minchinia nelsoni*, is a microscopic, one-celled animal, not a virus or bacterium as originally thought. There is presently no known cure for it. Since it can be deadly (to oysters, not to people), cleaning out as much as ninety-five percent of a local oyster population, extreme care should be taken in introducing transplanted oysters to an area already producing. (In Massachusetts, oyster seed to be transplanted must be checked for MSX by the Massachusetts Division of Marine Fisheries before it can be introduced to a new area.) If MSX exists, or if there is any history of its existence in your area, try to raise only local stock.

GONYAULAX TAMARENSIS

Gonyaulax tamarensis, commonly and erroneously called "red tide." "Paralytic shellfish poisoning [is] caused by the consumption of shellfish harvested . . . from coastal areas infested with the marine dinoflagellate *Gonyaulax tamarensis*.

This unicellular, microscopic alga synthesizes a potent toxin that is accumulated by shellfish during their normal feeding, but becomes a health problem only when great numbers of the organism are present in the waters overlaying shellfish harvesting areas . . ."*

Since no one is sure of the cause of the explosive blooms of this dinoflagellate, there is no known cure except time for shellfish containing dangerous amounts. Eventually the shellfish will clear itself (excepting bay scallops in which it is contained, according to tests, only in the viscera, and which may die anyway, having lived out their normal life span, before clearing.) Oysters are the shellfish least likely to contain *gonyaulax*, then quahogs. Clams and mussels are particularly susceptible, although mussels, being the first to show dangerous levels, are apt to be the first to clear themselves.

It is not harmful to shellfish, but it can cause paralytic shellfish poisoning in warm-blooded animals, ducks, gulls and people. An excess attacks nerve ends and eventually paralyzes respiratory organs. If you suspect you have it, get to an iron lung where the effects will gradually wear off, leaving you none the worse physically, but wiser. It is not the same organism which causes "red tide" either in Florida or the northwest coast of the United States. You would be well advised, particularly with blue mussels, to have the Massachusetts Department of Environmental Quality Engineering (formerly Department of Public Health) check.

MAN is, of course, the worst predator of all. With this in mind, use your shellfish resources lovingly. The very best conservation is to put back more shellfish than you take away.

* *The Paralytic Shellfish Poisoning Incident in Massachusetts*, by John C. Collins, Massachusetts Division of Environmental Health, December 1972.

GLOSSARY

Razor clam	*Ensis directus*
Sea clam	*Spisula solidissima*
Soft shell clam	*Mya arenaria*
Blue mussel	*Mytilus edulis*
American oyster	*Ostrea virginica*
European oyster	*Ostrea edulis*
Quahog	*Mercenaria mercenaria*
Bay (or Cape) scallop	*Pecten irradians*
Oyster drill	*Urosalpinex cinera*
Northern moonsnail	*Polinices heros*
Southern moonsnail	*Polinices duplicata*
Channeled whelk	*Busycon canaliculatum*
Knobbed whelk	*Busycon carica*
Blue crab	*Calinectus sapidus*
Green crab	*Carcinus maenus*
Horseshoe crab	*Limulus polyphemus*
Blister worm	*Polydora*
Boring sponge	*Cliona*
Flatworm	*Stylochus ellipticus*
Teredo (or Shipworm)	*Teredo navilis*
Starfish	*Asteries forbesi; A. vulgaris*
MSX	*Minchinia nelsoni*
"Red Tide" (causative)	*Gonyaulax tamarensis*
Eelgrass	*Zostera marina*
Japanese codium	*Codium* (sp)
Mermaids Hair	*Claudophora gracilis*
Sea lettuce	*Ulva lactuca*
Sedge grass	*Spartina alterniflora*

BIBLIOGRAPHY

Agricultural Newsletter from the Netherlands, No. 1, 1976.

Bailey, Robert S., and Biggs, Fred C. *Let's Be Oyster Farmers*, Gloucester, Va.: Virginia Institute of Marine Sciences, 1968.

Barr, G. J. *The Regulation of Shellfisheries by Sea Fisheries Committee*, London: A paper at the Sixth Shellfish Conference, May 1975.

Belding, Dr. David L. *A Report upon the Quahog and Oyster Fisheries of Massachusetts*. Boston: Massachusetts Department of Fisheries and Game. Originally published in 1912.

______. *The Soft-shelled Clam Fishery of Massachusetts*. Boston: Massachusetts Division of Fisheries and Game. Originally published in 1907 and republished with new material in 1916, and again in Nov. 1930.

Bouchard, Reggie. *Maine Mussels*. Augusta: Maine Department of Sea and Shore Fisheries, c. 1973-74.

Carr, H. Arnold. Biologist for Massachusetts Division of Marine Fisheries, 1975. Personal notes on shellfish predators in Massachusetts.

Castagna, Michael A. *Hard Clam Culture Method Developed at VIMS*. A Sea Grant Advisory Project, June 1970.

Cole, Dr. H. A., CMG. *Changes and Technical Advances in the Cultivation of Shellfish During the Last 40 Years.* London: A paper at the Sixth Shellfish Conference, May 1975.

Collins, John C. *The Paralytic Shellfish Poisoning Incident in Massachusetts.* Boston: Massachusetts Division of Environmental Health, November 1972.

Drinkwaard, Dr. A. C. *The Dutch Mussel Culture and Its Improvement Efforts.* Texel, the Netherlands: Mussel Experimental Station of the Netherlands Institute for Fishery, c. May 1975.

Hurlburt, C. Graham and Sarah W. *Blue Gold.* Duxbury, Massachusetts: privately printed, November 1974.

Lind, Henry, et al. *Aquaculture in Nauset Marsh.* Boston: funded by N.S.F.: Host Institute, Boston College, August 1972.

Medcoff, J. C. *Oyster Farming in the Maritimes.* Ottawa: Fisheries Research Board of Canada, 1961.

Prakash, A., et al. *Paralytic Shellfish Poisoning in Eastern Canada.* Ottawa: Fisheries Research Board of Canada, 1971.

Pratt, Rev. Enoch. *A Comprehensive History of Eastham, Wellfleet and Orleans from 1644 to 1844.* Yarmouth, Massachusetts: W. S. Fisher and Co., 1844.

Ropes, John W. *The Feeding Habits of the Green Crab.* Carcinus maenus. Oxford, Md.: Bureau of Commercial Fisheries Biological Laboratory, 1968.

Thompson, Peggy. *Value is Extracted from a Nuisance.* *Smithsonian* magazine, 1975.

Proceedings of a Workshop on Shellfish Management Program In New York State. New York: New York Sea Grant Institute, July 1975.

State laws pertinent to shellfish management from New York, Rhode Island, Connecticut, Maine, and Massachusetts.